PHONOLOGIC AND LEXICAL ROUTES TO READING: A COMPARISON OF IMPAIRED, NORMAL, AND SUPERIOR READERS

BY

MARY K. MORRIS

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A COMPARISON OF IMPAIRED, NORMAL, AND SUPERIOR READERS

BY

MARY K. MORRIS

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Chairperson: Eileen B. Fennell, Ph.D.
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Ninety 12-year-old males were classified as impaired, normal, and superior readers based on their reading percentiles on the Metropolitan Achievement Test. Two reading measures were administered to these children. The Battery of Adult Reading Function (BARF) is designed to assess the relative integrity of the phonological and lexical reading routes. It was developed based on a model of acquired reading disorders and has proven useful in differentiating subtypes of acquired alexia. Two primary subtypes have been described, resulting from impairment of one route with relative sparing of the other. The Brigance Diagnostic Inventory of Basic Skills was utilized to assess silent reading comprehension and reading rate.

The three reading groups were observed to differ both quantitatively and qualitatively on the BARF. Analyses were selected to test the hypothesis that subtypes of developmental reading

disorders are analogous to subtypes of acquired reading disorders. Two classification methods were chosen: (a) cluster analysis and (b) visual inspection, using a set of classification rules based on a model of alexia.

Results obtained with these two methods were congruent. Impaired readers were predominantly characterized by deficits in the phonological route. Selective deficits in the lexical route with spared phonological processing were not typical of this group. The ability to use the phonological route appears to permit normal reading achievement, even in the absence of well developed lexical skills. It was also hypothesized that lexical and phonological routes would differ in speed of processing. While the difference between the reading rates associated with those two routes was in the expected direction, it did not achieve significance. These findings are discussed in the context of a developmental model of reading acquisition in an attempt to explain why selective deficits in the lexical route do not result in impaired reading in children.

CHAPTER 1
INTRODUCTION

Models of Developmental Dyslexia: Historical Overview

According to the World Federation of Neurology, children with specific developmental dyslexia are those who fail to acquire normal reading proficiency despite conventional instruction, sociocultural opportunity, average intelligence, and freedom from gross sensory, emotional or neurological handicap (Critchley, 1970). Although substantial research attention has been devoted to this population over several decades, disagreement persists regarding the nature and etiology of this disorder. Rourke (1985) has recently reviewed the historical development of models of developmental dyslexia. The earliest theoretical models viewed developmental dyslexia as a unitary entity with a single causal deficit. Hinshelwood (1917) described cases of "otherwise sharp and intelligent" children who could not learn to read. He attributed this selective impairment of reading acquisition to "congenital visual word blindness," an inability to recognize words, resulting from damage to the visual memory center for words in the left angular gyrus. This model assumed a single type of reading disability that occurred as an isolated disorder in an otherwise completely normal child. It also explicitly connected the congenital disorder with the acquired impairment of reading ability following brain damage which had been observed in adults.

Prior to 1950, the only other major theory of developmental reading disorder was formulated by Orton (1937). Orton also believed that reading involved visual word images that were stored in a specific part of the brain. However, rather than attributing reading problems to deficits in these brain regions, he proposed a lag in the development of normal left hemisphere dominance for language abilities. Because of this developmental lag, visual images stored as mirror images in the nondominant hemisphere were not suppressed by the dominant hemisphere. This interhemispheric competition interfered with the perception of normally oriented visual images and resulted in "strephosymbolia" or "twisted symbols." Orton also attributed speech and writing problems, stuttering, and general clumsiness to this developmental lag. Thus, he began to move away from the notion of an isolated impairment of reading, postulating a relationship between reading problems and deficits in other nonreading abilities.

While both of these early models assume a unitary disorder based on neurological dysfunction, the differences between them anticipate controversial questions in future reading disability research. Does developmental dyslexia result from a specific deficit or a more general developmental lag? Are the impairments in reading isolated or secondary to difficulties in other nonreading abilities? And finally, are models of acquired reading dysfunction useful in understanding developmental disorders?

Exploration of nonreading skills became the central focus of reading disability research after 1950. Investigators began to search for an underlying nonreading skill deficiency which might cause

reading impairment. The dominant experimental method was the single syndrome paradigm (Doehring, 1978). In this paradigm, an experimental group of disabled readers was compared to a matched control group of normal readers on one or more measures of nonreading ability. Statistically significant differences between groups were accepted as evidence of underlying behavioral causes of reading disability. A wide variety of potential underlying causes were identified by such studies. Some examples include disturbance in the development of visual perception (Bender, 1958), directional confusion (Hermann, 1959), delayed left hemisphere specialization (Satz & van Nostrand, 1970), perceptual deficits (Cruickshank, 1968), and verbal processing deficits (Vellutino, 1978).

Follow-up studies consistently demonstrated that each of these unitary deficit hypotheses was inadequate to account for the diversity among reading disabled children. These failures of replication led to the gradual realization that the accumulation of contradictory and inconsistent findings may have been a function of heterogeneity in the population of interest. Several prominent researchers recommended that searches for the underlying causes of a unitary dyslexia be abandoned in favor of attempts to identify different categories of reading disability (Benton, 1975). During the 1970s, the search for subtypes dominated research in learning disabilities, in general, and developmental dyslexia, in particular.

Research on Reading Disability Subtypes

In a recent review of the learning disability subtype literature, Satz and Morris (1981) describe two different approaches to the

problem of subtype identification. The clinical-inferential approach utilizes both a priori assumptions about significant group attributes and visual inspection techniques to reduce large data sets into presumably homogeneous classes. Groupings have been based on (a) etiological inferences, (b) performance on neuropsychological/ cognitive measures, and (c) direct measures of reading achievement and/or performance. These techniques have been frequently criticized since they tend to reify a priori theoretical biases and cannot contend with the complexity of large multivariate data sets. However, valuable insights into significant clinical dimensions of dyslexia are likely to be gained.

Multivariate statistical methods (e.g., factor analysis and cluster analysis) have also been employed to create systems of classification by identifying the hidden substructure of complex multidimensional data sets. Such data sets commonly reflect performance on either neuropsychological and/or reading achievement measures. Studies employing a statistical approach to classification make no a priori assumptions regarding either number or type of subgroups in the solution. The use of statistical methods also allows the accommodation of much larger data sets than can be handled by visual inspection techniques. However, the validity of subtypes generated by these techniques has been questioned. These methods will create clusters from random data and the nature of the subtype solution is to some extent a function of the clustering algorithm chosen. Thus, current statistical classification approaches are also heuristic devices which require external validation.

Classifications based on inferred etiology and neuropsychological strengths and weaknesses comprise a substantial portion of the subtype literature. Classifications based on etiology have typically attempted to clinically identify a subset of reading disabled children whose difficulties are due to an intrinsic constitutional deficit. This syndrome has been termed "specific developmental dyslexia" (Critchley, 1970) or "primary reading retardation" (Rabinovitch, 1968). Rutter (1978) has argued that such classification schemes are based on a diagnosis by exclusion, involving circular reasoning, with only presumptive evidence of a constitutional basis. Taylor, Satz, and Friel (1979) were unable to distinguish a specific developmental dyslexic subgroup from nondyslexic poor readers along any of several dimensions including severity of reading disturbance, frequency of reversal errors, familial reading competency, or personality functioning.

Classifications based on nonreading abilities have employed both clinical inferential and multivariate statistical techniques. Since reading is a highly complex activity, dysfunction in a wide variety of component cognitive and/or linguistic skills is likely to produce impairment. Frequently cited studies utilizing a clinical-inferential approach include Denckla (1972); Kinsbourne and Warrington (1966); and Mattis, French, and Rapin (1975). A multivariate statistical approach based on a battery of neuropsychological measures is also exemplified in a growing body of literature (Fisk & Rourke, 1979; Fletcher & Satz, 1985; C. S. Johnston, 1986; Lyon, Stewart, & Freedman, 1982; Lyon & Watson, 1981; Petrauskas & Rourke, 1979; Rourke & Finlayson, 1978).

Although classifications based on etiology and on nonreading ability have provided important information about reading disability subtypes, the present discussion will focus on classifications based on direct measures of reading achievement and performance. This emphasis reflects the belief that the search for an underlying mechanism must begin with a careful analysis of the dysfunctional reading process itself rather than by examining related cognitive processes.

Classifications Based on Reading Achievement/Performance

Multivariate Statistical Techniques

Doehring and Hoshko (1977) utilized a Q-technique factor analysis to identify homogeneous subtypes of learning disabled children. Thirty-one separate tests of reading related skills were administered to two different groups of children, one with reading deficits (N=34) and another with mixed learning disabilities (N=31). The Q-technique clusters subjects (not test variables as in standard factor analysis) who show similar patterns of performance.

Three subgroups emerged within the reading disabled population. Type 1 (N=12) demonstrated good performance on both visual-visual and auditory-visual matching tests and deficits on oral reading tests (composed of single words and syllables). The authors attributed this pattern of performance to a linguistic deficit. The profile for Type 2 (N=11) was characterized by normal visual scanning, impaired auditory-visual letter matching, and impaired oral reading. Doehring and Hoshko (1977) described these children as phonologically deficient with particular difficulties in making grapheme-phoneme associations. Type 3 (N=8) were able to make visual-visual and

auditory-visual matches of single letters, but were unable to perform similar matches with syllables and words. The group was described as deficient in intersensory integration.

One of the strengths of the Doehring and Hoshko (1977) study was the attempt to validate the identified subtypes with an external criterion. An independent estimate of the reading skills of these children, based on teacher recommendations for compensatory educational procedures, was congruent with the hypothesized deficits. However, as Satz and Morris (1981) point out, the differences between subgroups on this independent criterion were not assessed by statistical procedures. In addition, no control group of normal readers was tested to determine whether the proposed subtypes were unique to a reading disabled population. Finally, the Q-technique of factor analysis has been criticized for its inability to deal with loadings on multiple factors and its insensitivity to elevation differences when creating subtypes (Satz & Morris, 1981).

Satz and Morris (1981) applied cluster analytic techniques to the large unselected sample (N=236) of 11-year-old white males who had participated in the Florida Longitudinal Project (Satz, Taylor, Friel, & Fletcher, 1978). Cluster analysis is a procedure designed to facilitate the creation of classification schemes. Several techniques have been developed to group individuals into homogeneous clusters based on each subject's performance on a set of clustering variables. In this study, cluster analysis was used to define a target population, prior to the search for subtypes.

Nine subgroups emerged, representing different patterns of reading, spelling, and arithmetic ability. Two of these groups were characterized by deficits in all three areas (N=89) and were consequently labeled "learning disabled." Validation of these subgroups using Peabody Picture Vocabulary Test-IQ (PPVT-IQ), neuropsychological performance, neurological status, and socioeconomic status (SES) was also reported. The "learning disabled" groups had lower PPVT-IQs, poorer performances on both language and perceptual tests, more "soft" neurological signs, and lower SES. Although this study illustrates the use of cluster analysis based on achievement variables it explored subtypes within a broad spectrum of learning disabilities. Consequently, it does not specifically address the problem of developmental dyslexia subtypes.

Clinical-Inferential Techniques

Several studies have relied on clinical observation of the reading process as a basis for subtype classification. Monroe (1932) identified ten types of errors made by children with reading difficulty. However, patterns of error type did not differentiate among reading disabled, mentally retarded, and behavior disordered subjects. Ingram, Mason, and Blackburn (1970) also used error type to classify reading disabled subjects into audiophonic, visuospatial, and mixed subtypes.

Boder's (1973) qualitative analysis of the patterns of reading and spelling in a sample of dyslexic children has had considerable influence on the subtype literature. Using this approach, she identified three subtypes in a sample of 107 children, ages 8 - 16,

who met the World Federation definition of specific developmental dyslexia. Subtype 1 was described as "dysphonetic" with selective impairments in analyzing phonemic properties of language. They experienced difficulties in both sounding out and blending the component graphemes of words and syllables, preferring to approach written material in a more global fashion, based on the visual recognition of whole words. Sixty-seven percent of Boder's sample fell into this group. Subtype 2 was labeled "dyseidetic" based on their deficiencies in discriminating and remembering visual gestalts. These children read very slowly, relying on phonemic analysis to sound out each word as if they were encountering it for the first time. This group comprised 10% of the sample. Finally, Subtype 3 was described as a mixed dysphonetic-dyseidetic group with impairments in both phonemic analysis and visual gestalt discrimination. Twenty-three percent of this population were classified in the mixed subtype.

Boder (1973) also described a characteristic pattern of errors associated with each subtype. Dysphonetic readers lacked phonemic analysis skills and had difficulty blending the component letters and syllables of a word. Thus, words were often guessed from minimal cues such as the first or last letter and the length of the word. Word substitutions were pathognomonic of this group. These substitutions were often based on visual similarity between the target word and the response. Occasionally, substitution errors based on a conceptual, but not visual or phonetic resemblance, occurred. Boder (1973) refers

to these as "semantic substitution" errors and cites examples such as "funny" for "laugh," "chicken" for "duck," and "planet" for "moon."

In contrast, dyseidetic children appeared to rely on phonemic analysis and synthesis, sounding out letters in sequence, to compensate for their hypothesized deficits in processing visual gestalts. Errors commonly occurred on irregular words which do not conform to grapheme to phoneme conversion rules. Responses reflected the child's attempt to sound out these words by applying conversion rules.

The mixed dysphonetic-dyseidetic group was described as the most severely handicapped due to deficits in both processing mechanisms. Boder characterized these children as nonreaders and described their errors as bizarre in that they bore little resemblance to the target on any dimension. Confusion of reversible letters occurred more frequently in these children but was present to some degree in all three groups.

Although Boder's (1973) study has been commended for its rich clinical descriptions of both reading styles and error patterns, her subtypes remain clinical impressions which require statistical verification of their validity, reliability, and utility. Although parallels can be drawn between these groups and those reported by other investigators (Aaron, 1982; Denckla, 1972; Mattis et al., 1975; Myklebust, 1968), the globally similar labels used by independent researchers may actually refer to disparate patterns. Furthermore, Boder's clinical analysis was not extended to a comparison group of normal readers in order to directly address the issue of quantitative

vs. qualitative differences in the reading performance of dyslexics relative to normal readers.

Aaron (1982) has proposed a model of developmental dyslexia based on constructs utilized by cognitive psychologists to describe the reading process. The encoding operation in normal reading is believed to involve two dissociable information processing strategies, simultaneous and sequential (Das, Kirby, & Jarman, 1979). The simultaneous operation is characterized by the parallel processing of several letters within a word, resulting in the encoding of visual word images as gestalts. The sequential operation involves a serial conversion of individual letters to their phonetic equivalents. It is hypothesized that skilled reading is based on the concurrent implementation of both encoding operations (Das et al., 1979). Thus, an underutilization of one or the other of these strategies is believed to hinder efficient reading. Aaron (1982) attributes developmental dyslexia to an imbalance in the deployment of these contrasting operations. This model appears to be congruent with Boder's (1973) typology in that her dysphonetic group could be described as sequential-deficient and her dyseidetic group, simultaneous-deficient.

Attempts to empirically demonstrate the existence of the two clinical subtypes suggested by this hypothesis have been reported (Aaron, 1982). This author utilized Boder's (1973) diagnostic screening inventory to classify dyslexic children into sequential-deficient and simultaneous-deficient groups. Subjects were presented with a list of words of graded difficulty and asked to read each

aloud. Based on their performance on this task, they were asked to write ten of those words to dictation. Five words which were read without hesitation and five read with difficulty were presented. These were presumed to reflect sight vocabulary and unknown vocabulary, respectively. Subjects were classified into the two subgroups on the basis of spelling errors on the dictation task. Sequential-deficient dyslexics were characterized by visual word substitutions and a tendency to omit, reverse or displace letters within a word. Simultaneous-deficient dyslexics produced phonetic misspellings which reflected an application of grapheme-phoneme correspondences.

After this initial screening, children in each subtype were matched on the basis of chronological age, mental age, and sex, resulting in 14 pairs. Another matched group of 14 normal readers served as a control group. Four measures assumed to reflect either a sequential or a simultaneous processing strategy were administered: (a) a memory for faces test (simultaneous), (b) Wechsler Intelligence Scale for Children-Revised (WISC-R) Digit Span (sequential), (c) written reproduction of closely paired letter stimuli as either a single gestalt (simultaneous) or as two discrete letters (sequential), and (d) written reproduction of individual letters and shapes. On the final measure, mirror image errors on a delayed reproduction task were interpreted as evidence for simultaneous processing of the stimulus as a visual gestalt without regard for left-right orientation.

Performance on this battery supported the existence of two distinct subgroups of dyslexic children. The simultaneous-deficient

group was impaired on the memory for faces task relative to the sequential-deficient and control groups. Conversely, the sequential-deficient group was impaired on Digit Span and made more mirror image reversals in their delayed reproductions of letters and shapes. Finally, the sequential-deficient group also reproduced closely paired letters as a single fused gestalt more frequently than the other two groups. Aaron (1982) concludes that these results are congruent with his hypothesis that dyslexic children are characterized by an imbalance in encoding strategies which is not characteristic of normal readers. His findings also support the construct validity of Boder's (1973) subtypes and the processing strategies that she associated with them.

Surface vs. Deep Dyslexia

Studies of alexia, an acquired reading disorder secondary to neurological damage, have also focused on the identification of subtypes with different clinical presentations. Marshall and Newcombe (1966, 1973) have described two dissociable symptoms in alexic patients based on an examination of reading errors. These investigators propose that reading impairment resulting from left hemisphere damage reflects a disruption of one of the two processing routes necessary for normal reading.

One reading route or mechanism, referred to as "visual," "lexical," or "whole word," involves visual recognition of the printed word as a unitary entity. Once recognized, the visual word form is believed to directly access its semantic representation, without phonologic mediation. The second route, described as a "phonologic"

or "grapheme-to-phoneme" conversion process, requires the derivation of a phonemic representation of the printed form by the application of conversion rules, prior to accessing semantics (Coslett, Gonzalez-Rothi, & Heilman, 1985).

Disruption of each of these reading mechanisms is associated with a characteristic pattern of reading deficits. Impairment of the visual or whole word mechanism has been termed "surface dyslexia" (Marshall & Newcombe, 1973). These patients have difficulty reading aloud orthographically irregular words, for which there is no direct grapheme-to-phoneme correspondence. They read by means of a direct letter-by-letter phonemic transcoding, resulting in paralexic errors which are phonologically similar to the target word.

Another group of alexic patients is able to read familiar (high frequency) words, regardless of their conformity to phonemic conversion rules. Their errors are primarily visual or semantic in nature, rather than phonemic substitutions. However, they are unable to read either nonsense words or function words such as prepositions and articles. Their reading performance improves with concrete words or words presented in a semantic context. Marshall and Newcombe (1973) referred to this syndrome as "deep dyslexia."

Alexic reading patterns reflect both deficits in the processing system and available compensatory strategies employed to overcome these deficits. A direct analysis of reading errors is an essential tool for the identification of both impaired and spared routes in patients with acquired reading disorders. Four types of errors are commonly described in the literature on acquired alexia.

Semantic errors are responses which are within the same semantic category as the target word. Coltheart (1980) describes two types of semantic errors. In the first type, the response is a synonym of the target. For example, the target "merry" might be read as "happy." Coltheart refers to this as a shared feature semantic error. In fact, this type of semantic error may be divided into two categories. The first subtype is the superordinate error in which the response is a semantic superordinate of the stimulus (e.g., robin → "bird"). The second is the co-ordinate error in which both target and response are exemplars of a single semantic category (e.g., robin → "sparrow"). Subordinate errors (e.g., dog → "poodle") are logically possible but rarely encountered. The second category of semantic errors is characterized by an associative link between target and response (e.g., merry → "Christmas").

Phonemic errors sound like the target word. These can also be divided into two types. Some phonemic errors result from an impairment of the grapheme-to-phoneme conversion process. Others result from the misapplication of the rules of English orthography. For example, failure to apply the rule that a terminal "e" lengthens the preceding vowel would result in the response "cap" for "cape."

Visual errors are responses which are visually similar to the target, sharing a significant number of graphemes (e.g., chair → "chain"). Finally, derivational errors are responses which share a common root morpheme with the target word (e.g., walk → "walking"). Overlap between these categories occurs frequently, particularly for visual and phonemic errors. This classification problem has often

resulted in the introduction of additional categories for errors which meet the criteria for more than one type.

Reading Development and Reading Routes

Studies of reading development have supported the existence of two general mechanisms used by children who are learning to read words. One mechanism is based on spelling-sound correspondence rules or "phonics." The other mechanism relies on direct knowledge about the visual word form. "Look-say" teaching techniques capitalize on this mechanism. The phonic approach is useful in reading orthographically regular words and nonsense words. It is also the only method available when the developing reader faces a new and unfamiliar word. The visual approach cannot be used to read nonsense words or novel words, but is well suited for reading familiar words and orthographically irregular words which do not conform to spelling-sound correspondence rules. The relative importance of these two mechanisms and the efficacy of teaching techniques emphasizing one or the other have been controversial topics in educational philosophy.

Rather than opting for one or the other of these extreme viewpoints, one might assume that both the look and the sound are important for children learning to read. Frith (1985) has postulated a three-phase theory of reading acquisition that emphasizes the predominance of different processing stategies at different stages of development. The following three stages are hypothesized to occur in invariant sequence. Each new strategy is assumed to capitalize on the previous one.

The logographic phase encompasses the initial phase of reading acquisition. Reading during this stage is based on logographic skills which permit the instant recognition of familiar words, probably on the basis of salient features. Phonologic features are secondary to recognition. The use of the logographic strategy allows the child to amass a sizeable sight vocabulary. Reading by the "look-say" method emphasizes these skills.

At the second phase, an alphabetic strategy is adopted. Alphabetic skills involve the knowledge and use of grapheme-phoneme correspondence rules. This is an analytic skill, based on a systematic, sequential approach. During this stage, the child learns more than letter-sound correspondence; the more complex and context sensitive rules of English orthography are acquired during this phase. The teaching of "phonics" emphasizes the alphabetic strategy.

Finally, the developing reader adopts an orthographic strategy. This strategy permits the instant analysis of words into orthographic units without intervening phonological conversion. These orthographic units are believed to correspond to morphemes and are internally represented as abstract letter-by-letter strings. Frith (1985) describes this strategy as both nonvisual and nonphonological. It is viewed as the product of a merger of instant recognition and sequential analytic skills, each of which has been predominant at an earlier phase.

Frith's (1985) model does not address how each of the initially acquired strategies is continued in skilled reading. The degree to which each distinct strategy remains accessible and continues to be

employed is unknown. Clearly, a variety of contextual variables would play a key role in the pattern of strategy utilization.

Acquired Alexia and Developmental Dyslexia

The literature on both normal reading development and developmental dyslexia in children provides convergent support for the existence of two distinct processing mechanisms in reading. Without empirical demonstration, one cannot assume the identity of processing routes referred to by different names. However, the apparent similarity between "phonologic," "sequential," and "alphabetic" strategies on the one hand, and between "visual," "simultaneous," and "logographic/orthographic" strategies on the other, is quite compelling. More importantly, the same set of constructs has proven useful in understanding the loss of reading competence in adults after brain injury. Unfortunately, the studies of acquired and developmental reading disorders have proceeded independently, with only occasional acknowledgement of congruent findings. However, there has been some recent discussion concerning the possibility that developmental dyslexia may exhibit similarities to one or more of the syndromes of acquired alexia.

Jorm (1979) proposed that developmental dyslexia is similar to deep dyslexia (Marshall & Newcombe, 1973) in that developmental dyslexics have a specific impairment of the ability to process written material via a phonological route. He cites unpublished work by Firth in 1972 in which groups of dyslexic and normal readers were given a large battery of tests believed to tap various component skills in the reading process. According to Jorm (1979), Firth found that tests of

nonsense word reading, auditory blending, and auditory analysis best discriminated the two groups. The information presented was insufficient to evaluate these findings. In particular, the selection criteria for subjects and the means of assessing visual word form processing were not described. Jorm (1979) also points out that dyslexics have been shown to learn the meanings of logographic Chinese characters with ease (Rozin, Poritsky, & Sotsky, 1971) and are comparable to normals in their ability to directly associate meanings with word-like visual forms (Jorm, 1977).

On this basis, Jorm (1979) concludes that the visual processing route is intact and that developmental dyslexia results from a unitary deficit in phonological processing. He attributes this deficit to dysfunction of the left inferior parietal lobule. No evidence that developmental dyslexics present with other aspects of the deep dyslexia syndrome, such as semantic, visual, and derivational errors, impaired reading of functors, or an imageability effect was presented.

In fact, although Boder (1973) makes reference to "semantic substitution" errors, such errors are rarely reported in clinical descriptions of developmental dyslexics. However, two recent papers have supported their occurrence in this population. R. S. Johnston (1983) presented data from an 18-year-old disabled reader who produced semantic errors when reading aloud single words. This patient showed the same pattern of reading errors as the cases of acquired deep dyslexia reported in the literature (Coltheart, Patterson, & Marshall, 1980). She made semantic, visual, derivational, and function word substitution errors and was unable to read nonwords. She also showed

imageability and part of speech effects. However, the proportion of semantic errors was only 3%. Thus, this patient's reading disturbance may be more similar to the acquired alexia known as phonological alexia (Beauvois & Derouesne, 1979; Shallice & Warrington, 1975). Phonological alexics have a severe impairment of the phonological reading route, as evidenced by their inability to read nonsense words, but do not make semantic errors in reading aloud. Temple and Marshall (1983) have reported a case study of developmental phonological alexia in a 17-year-old girl of average intelligence. She was impaired at nonword reading relative to word reading and frequently responded to nonwords with lexicalizations. A large proportion of her errors were derivational and visual paralexias. No semantic errors were noted.

More recently, Siegel (1985) presented evidence for semantic errors in reading single words in a group of six dyslexic children, ages 7 and 8. These children were unable to read even simple nonwords. Siegel and Ryan (1984) have demonstrated the ability to read simple nonwords in normal readers of this age. The majority of their responses were omissions; however, when responses were given, they were frequently real words. Lexicalization of nonwords in this manner has been described in deep dyslexic adults (Marshall & Newcombe, 1973). Two comparison groups, normal controls and other dyslexic children, were employed. No semantic substitutions occurred in either control group. Thus, Siegel (1985) raises the possibility that only a small subset of dyslexic children will exhibit reading deficits analogous to those associated with the syndrome of deep dyslexia.

Other authors have argued that developmental dyslexia is analogous to surface dyslexia as described by Marshall and Newcombe (1973). Marshall and Newcombe attributed surface dyslexia to a moderate to severe impairment of the direct route from visual written forms to semantic representations, combined with a lesser deficit in knowledge of grapheme-phoneme correspondences. The vast majority of errors in this group of patients can be described as partial failures of grapheme-phoneme conversion rules, in particular, context sensitive rules.

Holmes (1978) studied single word reading in four male dyslexics, ages 9 - 13, and reported that the majority of errors made by these subjects were conversion failures. They had difficulty reading irregular words and typically produced regularization errors. Coltheart, Masterson, Byng, Prior, and Riddoch (1983) described several cases of surface dyslexia, both developmental and acquired. The two groups were characterized as quite similar in reading performance. However, all of the developmental surface dyslexics also made visual errors, suggesting some incompetence of the phonologic route as well. In contrast, acquired surface dyslexics exhibited greater variability in the commission of visual errors; some adult patients never made errors of this type. Finally, Temple (1984) presented the case of a 13-year-old male with epilepsy, diagnosed at 18 months. His reading performance was consistent with surface dyslexia in that he had difficulty with irregular words and displayed homophone confusion. However, unlike the developmental surface

dyslexics described by Coltheart et al. (1983), this patient made no visual errors. All of his misreadings were strictly rule governed.

Temple (1985) has proposed an expanded model of the phonological route and utilized this model to more accurately isolate the nature of the hypothesized phonological impairment in four developmental dyslexics. Phonological processing is divided into three main stages: (a) parser, (b) translator, and (c) blender. The parser divides the grapheme sequence into a number of segments or chunks. Chunks may consist of single or multiple graphemes. The translator assigns each chunk to one of several potentially valid phonological representations. Finally, these phonologic correspondences are combined in the blender. Dysfunction at each of these stages would result in a different type of error. Temple was able to demonstrate qualitative differences in the performances of the developmental surface dyslexics which could be explained by the expanded model. Some cases appeared to represent a pure impairment of a single stage of phonological processing while others were suggestive of more widespread impairment.

It appears that initial efforts to apply knowledge about acquired alexia to the study of developmental dyslexia have focused on identifying the developmental disorder with one or the other of the acquired syndromes. An awareness of heterogeneity, evident in the dyslexia subtype literature, appears to have been replaced by the unitary deficit model in the papers described above. A notable exception to this trend is the meticulous analysis of reading functions in four developmental dyslexics reported by Seymour and

MacGregor (1984). Based on an information processing model of reading, specific cognitive-experimental paradigms were selected to assess the functional integrity of the visual and phonological processors and of semantic access. Error and reaction time data were collected.

Findings strongly supported the existence of subtypes. Each of the four developmental dyslexics exhibited a distinct pattern of impairment with differential involvement of the hypothesized processing mechanisms. Case 1 was described as a case of developmental phonological dyslexia with a primary deficit in the phonological processor. Knowledge of grapheme-phoneme correspondence was impaired with consequent inability to read nonwords. Case 2 was described as developmental morphemic dyslexia based on a primary defect in the wholistic function of the visual processor. This subject was unable to handle letter arrays as wholes and was restricted to letter-by-letter processing compatible with the phonological processor. Case 3 exhibited impairments of both the visual and the phonological processor and was thus termed multicomponent dyslexia. Finally, Case 4 appeared to have a restricted impairment in the analytic function of the visual processor. Seymour and MacGregor (1984) refer to this as developmental visual analytic dyslexia. They propose that dysfunction at this level of processing affects the speed at which the visual processor can operate in the analytic mode without preventing the development of the phonological or the visual wholistic processors.

Therefore, such dysfunction is primarily manifested in slowed response times, particularly with nonwords which require segmental parsing.

A recent study in a closely related area provides support for both the existence of two dissociable processing systems for written language and the similarity of developmental and acquired disorders. Roeltgen and Tucker (1986) examined acquired and developmental agraphia. Acquired agraphia refers to an impairment in the production of written language secondary to neurological damage. Agraphia may be secondary to motoric deficits resulting in poor grapheme formation or may reflect linguistic deficits as evidenced by specific patterns of spelling disability. Assessment of linguistic agraphia patients has supported the existence of two distinct spelling systems, one phonological and one lexical or orthographic (Roeltgen & Heilman, 1985). These systems appear to be analogous to the phonological and lexical reading mechanisms. Roeltgen and Tucker (1986) analyzed the spelling performance of 22 adolescent and adult subjects with developmental agraphia and compared it to that of control subjects and subjects with acquired agraphia. Both developmental and acquired agraphics could be divided into phonological and lexical groups. More importantly, the two groups of subjects with a developmental disorder were almost indistinguishable from the two groups of subjects with an acquired disorder. The only significant difference involved the spelling of regular words. Both nonword and regular word spelling were impaired in the acquired phonological agraphics. In developmental phonological agraphics, regular word spelling was preserved relative to the spelling of nonwords.

Statement of Purpose

Several lines of evidence have been discussed, all of which support the existence of strong parallels between developmental and acquired reading disorders. The notion of two distinct subtypes based on the relative impairment and preservation of two dissociable processing mechanisms is also consistent with theories of normal reading which postulate dual reading routes. Such parallels are not surprising. If ontogenetic development is assumed to proceed along clearly delineated paths, then degeneration is likely to proceed along these same paths which would serve as natural lines of fracture (Aaron, Baxter, & Lucenti, 1980).

Unfortunately, awareness of these parallels has rarely been translated into empirical exploration. Direct and systematic investigation of phonological and lexical reading deficits in children, with paradigms designed to highlight acquired/developmental parallels, have been rare. In particular, despite widespread discussion of the relative merits of phonologic vs. whole word reading, there has been little effort directed toward developing clinical measures designed to disentangle these two reading mechanisms in children. The assessment system of Boder and Jarrico (1982) represents an initial step in this direction. However, their system is not based on either a theory of the reading process or a model of the neurological basis of reading.

Fortunately, such a measure has been developed for adults. Gonzalez-Rothi, Coslett, and Heilman (1984) have developed a clinical tool, the Battery of Adult Reading Function, to identify the integrity

of the lexical and phonological routes to reading in patients with acquired alexia. The direct analysis of reading errors is an essential component of this measure. Dissociation of these two reading processes was demonstrated using this battery in a patient with mixed transcortical aphasia (Coslett et al., 1985). Their findings suggested that the lexical and phonologic conversion systems were both functionally and anatomically distinct.

The Battery of Adult Reading Function contains six subtests and two appendices. Subtests 1 - 4 contain 30 words each, to be read aloud by the subject. All word lists are balanced for both word frequency (Kucera & Francis, 1967) and number of graphemes per word. Each subtest contains the following word type: (a) Subtest 1--phonologically possible nonwords, (b) Subtest 2--regular words, (c) Subtest 3--rule governed words, and (d) Subtest 4--irregular words.

Subtests 5 and 6 assess silent reading. Subtest 5 consists of 2 practice plates and 18 test plates each containing one picture and two printed words. The words are homophonic but not homographic (identical sound but different spelling) and the subject is asked to point to the word that goes with the picture. Target words and foils are matched for word frequency and number of graphemes. Subtest 6 contains 2 practice and 18 test plates, each containing one word and three pictures. Each word is a nonword which is homophonic to a real English word. The subject's task is to point to the picture which depicts that real word. Words depicted by the other pictures begin with the same phoneme as the target word and are again matched for word frequency and graphemes.

Appendix A assesses the subject's ability to read functors. Sixty words are presented to be read aloud; 30 are contentives (nouns, verbs, and adjectives) and the remainder are functors (prepositions and articles) matched for frequency and graphemes. Appendix B tests written production by dictating individually the word pairs used in Subtest 5 within the context of a sentence.

On Subtests 1 - 4, the subject's oral production is scored both for accuracy and specific error type. The following error types are described in the battery manual:

1. semantic--a semantic associate of the target (ocean for fish),
2. phonologic--phonologically similar to the target (fine for phone),
3. visual--visually similar to target; no more than 30% of graphemes different (cat for eat),
4. visual/phonological--visually and phonologically similar (fin for fun),
5. derivational--words sharing a common root morpheme (jump for jumping),
6. other--any not included above. (Gonzalez-Rothi et al., 1984, p. 6)

Subtests 5 and 6 and Appendix A are scored for error rate. The writing test included in Appendix B is scored for both error rate and error type (homophonic/nonhomograph or other).

Gonzalez-Rothi et al. (1984) make the following predictions regarding differential reading performance by subjects relying on the lexical or the phonological route. Subjects employing a lexical route

should read aloud regular, rule governed, and irregular words better than nonwords. Errors should be predominantly visual or semantic. Performance on Subtest 5 should be superior to Subtest 6 since 5 is based on semantic guidance while 6 requires phonologic transcoding. Finally, on Appendix A, particular difficulty reading functors relative to contentives is predicted.

Conversely, the use of a phonological route should lead to difficulty in reading irregular words relative to nonwords, regular words, and possibly rule governed words. Errors should be primarily phonological and performance on Subtest 6 should be superior to Subtest 5. Reading of functors in Appendix A should be equivalent or superior to the reading of contentives.

This study employed the Battery of Adult Reading Function (Gonzalez-Rothi et al., 1984) to assess the integrity of the phonological and lexical reading mechanisms in a group of reading-impaired children. This measure has proven useful in distinguishing subtypes of acquired alexia and has been designed to reflect a sixth grade reading level. Thus, it should be appropriate with older children. Use of a measure from the acquired alexia literature maximized the comparability of subtypes which emerged. Utilization of the Battery of Adult Reading Function also allowed the direct examination of both oral and silent reading, unconfounded by spelling and writing. Previous studies (Aaron, 1982; Boder, 1973) have equated input and output mechanisms by focusing on spelling errors in their classification schemes. However, reading and spelling, although closely related, utilize different neurological mechanisms (Frith, 1983; Heilman & Rothi, 1982).

The performance of an impaired reading group on this battery was compared to the performance of age matched groups of normal and superior readers. The majority of studies of reading disability subtypes have not included these controls. Their inclusion made it possible to determine whether these same subtypes occur in unimpaired readers or are idiosyncratic to the impaired group. The assumption that utilization of both routes is necessary for skilled reading was also evaluated by examining these unimpaired groups.

A timed passage comprehension task, the Brigance Diagnostic Inventory of Basic Skills (Brigance, 1977) was also administered. This measure permitted an assessment of both silent reading comprehension and reading rate. The two hypothesized reading routes should differ in processing speed, i.e., lexical processing should occur more rapidly than phonological processing. Reading rates of lexical and phonological readers, classified by the Battery of Adult Reading Function, were compared. The Brigance Diagnostic Inventory of Basic Skills also provided an independent assessment of reading comprehension in these subjects.

Finally, the application of an acquired alexia model to developmental dyslexia has the advantage of facilitating an understanding of the hypothesized neurological basis of this disorder. Localization of brain lesions in alexic patients has provided valuable information regarding the anatomic substrate for each of the hypothetical processing mechanisms (Heilman & Rothi, 1982). The proposed neurological etiology for developmental dyslexia has proven difficult to demonstrate. It is likely that this

difficulty results from the nature of the neuropathology, which may be at a microstructural level. Galaburda and his colleagues (Galaburda & Kemper, 1979; Galaburda, Sherman, Rosen, Aboitiz, & Geschwind, 1985) have reported cytoarchitectonic abnormalities in several developmental dyslexics who have come to autopsy. These abnormalities were in the region of the left angular gyrus. The identification of parallels between acquired and developmental reading impairments may provide important clues as to the location of such subtle abnormalities.

The following general hypotheses were proposed:

1. Impaired, normal, and superior readers will exhibit different patterns of performance on the Battery of Adult Reading Function (BARF).
2. Subtypes based on pattern of performance on the BARF will be identifiable only within the impaired group.
3. Impaired, normal, and superior readers will exhibit different patterns of performance on the Brigance Diagnostic Inventory of Basic Skills (Brigance).
4. Performance on the BARF will be related to reading rate on the Brigance.

The following specific predictions were tested:

1. Impaired readers will make more errors and have slower response times on BARF as compared to normal and superior readers.
2. Normal and superior readers will not have significantly different error rates on the BARF.

3. Superior readers will have more rapid response times on the <u>BARF</u> relative to normal readers.
4. Within the impaired group, three subgroups will be identifiable based on their patterns of performance on the <u>BARF</u>.
   A. A phonological reading group will be characterized by the following pattern of responding:
      1) Increased errors and/or response time on Subtest 4 relative to Subtest 1.
      2) The production of neologistic responses on Subtest 1.
      3) Increased errors and/or response time on Subtest 5 relative to Subtest 6.
      4) Error rate and response time for functors in Appendix A equal to or less than for contentives.
      5) A predominance of phonological and visual/phonological errors.
   B. A lexical reading group will be characterized by the following:
      1) Increased errors and/or response time on Subtest 1 relative to Subtest 4.
      2) The production of lexical (real word) responses on Subtest 1.
      3) Increased errors and/or response time on Subtest 6 relative to Subtest 5.
      4) Error rate and response time for functors in Appendix A greater than for contentives.

5) A predominance of visual, derivational, and semantic errors.

C. A mixed deficit reading group will be characterized by the following:

1) Increased errors and/or response time on both Subtest 1 and Subtest 4.

2) The production of lexical (real word) responses on Subtest 1.

3) Increased errors and/or response time on both Subtest 5 and Subtest 6.

4) Error rate and response time for functors in Appendix A equal to contentives.

5) The presence of all error types.

5. Analogous subtypes within normal and superior readers will not be observed.

6. Impaired readers will make more errors and have slower reading rates on the Brigance as compared to normal and superior readers.

7. Normal and superior readers will not have significantly different error rates on the Brigance.

8. Superior readers will have more rapid reading rates than normals on the Brigance.

9. Those subjects whose performance on the BARF suggests a lexical reading route will have more rapid reading rates than

those subjects whose BARF performance suggests a phonological reading route.

CHAPTER 2
METHODS

Subjects

Ninety subjects were selected from the population of 12-year-old males enrolled in the Alachua County school system. They were chosen on the basis of their reading scores on the Metropolitan Achievement Test (1978), standardly administered by this school district. This measure is self-administered and involves reading brief stories and answering multiple choice questions about them. Thus, it is best described as a test of silent reading comprehension. Three groups were defined, each composed of 30 subjects. Impaired readers had reading percentile ranks which placed them at least 2 years below their current grade level. Normal readers had reading scores within 1 year of current grade level. Superior readers had attained scores which placed them at least 2 years above current grade level. All subjects had obtained a standard score of 80 or above on the Otis-Lennon School Abilities Test (1979), also standardly administered by the school district. This measure is also a self-administered multiple choice test. It is designed to assess a wide variety of cognitive abilities related to scholastic aptitude. However, its method of administration and verbal format suggest that reading comprehension skills are essential to performance. Subjects were identified from school records. Parents were contacted by

telephone and interviewed regarding their child's developmental history. Children with gross sensory, emotional or neurological handicaps were not chosen to participate. Parents who agreed to participate were mailed an informed consent form (see Appendix 1) which was to be returned to their child's teacher.

Stimulus Materials

Task 1: Battery of Adult Reading Function

All reading subtests of the Battery of Adult Reading Function (Gonzalez-Rothi et al., 1984), i.e., Subtests 1 - 6 and Appendix A were administered. Subtests 1 - 4 contain 30 words each, to be read aloud by the subject. Each word was printed in lower case letters on a 3 X 5 card to allow individual presentation. Word lists in each subtest are balanced for both word frequency (Kucera & Francis, 1967) and number of graphemes per word. Each subtest contains the following word type: (a) Subtest 1--phonologically possible nonwords (see Appendix 2), (b) Subtest 2--regular words (see Appendix 3), (c) Subtest 3--rule governed words (see Appendix 4), and (d) Subtest 4--irregular words (see Appendix 5).

Subtests 5 and 6 assess silent reading. Subtest 5 consists of 2 practice plates and 18 test plates, each containing one picture and two printed words. The words are homophonic but not homographic (i.e., identical pronounciation but different spelling) and the subject is asked to point to the word that goes with the picture. Target words and foils are matched for word frequency and number of graphemes (see Appendix 6). Subtest 6 contains 2 practice and 18 test plates, each containing one word and three pictures. Each word is a

nonword which is homophonic to a real English word. The subject's task is to point to the picture that depicts that real word. Words depicted by the other pictures begin with the same phoneme as the target word and are again matched for word frequency and number of graphemes (see Appendix 7).

Appendix A assesses the subject's ability to read functors. Sixty words are presented to be read aloud; 30 are contentives (nouns, verbs, and adjectives) and the remainder are functors (articles and prepositions), matched for frequency and number of graphemes (see Appendix 8). Each word was printed in lower case letters on a 3 X 5 card. Words were presented individually in a manner identical to Subtests 1 - 4.

Task 2: Brigance Diagnostic Inventory of Basic Skills

Reading rate and comprehension were assessed using the Brigance Diagnostic Inventory of Basic Skills (Brigance, 1977). This measure consists of paragraphs of approximately 100 words, equated for units of information, which the subject is asked to read silently. Passage reading is timed in order to calculate a reading rate in words per minute. Comprehension of each paragraph is measured by the subject's accuracy in responding to five multiple choice questions. The five questions assess comprehension on a literal level, focusing on clearly stated factors or details, sequence, cause and effect, vocabulary, and main theme. Paragraphs are graded in difficulty from the primer to the eleventh grade level.

Apparatus

Oral reading responses on Subtests 1 - 4 and Appendix A were audiotaped using a Sony Walkman Professional Stereo Cassette-Corder, Model WM-D6, augmented by a Realistic Omnidirectional Electret Tie Clip Microphone, Model 33-1056. Recordings were made on Maxell XLII-90 Epitaxial cassettes. Reaction times and reading rate were recorded on a Micronta LCD Quartz Chronograph, Model 63-5009A, accurate to 1/100 of a second.

General Procedure

Testing sessions were scheduled at the subject's school after parental informed consent was returned. Each subject completed the measures in a single testing session, lasting approximately 1 hour. Subjects were tested individually in a quiet room. Order of administration of the two measures was counterbalanced within each reading ability group. Order of subtest presentation on the *Battery of Adult Reading Function* was standardized for all subjects. Subtests 1 - 6 were administered in sequence, followed by Appendix A. Only the first response produced for each stimulus was scored.

Specific Procedures

Task 1: Battery for Adult Reading Function

In Subtests 1 - 4 and Appendix A, the subject was presented with a 3 X 5 card on which a single word was printed in lower case letters and instructed to read it aloud. On Subtest 1, subjects were informed that the stimuli were nonwords and asked to pronounce them as they thought they should be pronounced. If a real word was produced, the instructions were repeated. Subsequent real word responses were not

followed by reminders. The examiner phonetically transcribed each response and scored its accuracy. Reaction times for each stimulus word were obtained using a manually operated stopwatch. An audiotape of each subject's responses was recorded in order to permit an assessment of inter-rater reliability both for response accuracy and classification of error type. In Subtest 5, the subject was presented with the standard test plate and instructed to "Point to the word that goes with the picture." In Subtest 6, the subject was told that, "Although this isn't a real word, it sounds like a real word that goes with one of these pictures. Point to the picture that goes with the word." Response choice and reaction time were recorded for Subtests 5 and 6.

Task 2: Brigance Diagnostic Inventory of Basic Skills

Each subject was presented with a typed paragraph commensurate with his reading grade level. He was instructed to, "Read this paragraph silently as quickly and carefully as you can. I will be asking you some questions about it when you're done. Begin when I say 'Go' and let me know when you are finished." Reading time was recorded by manually operated stopwatch. Immediately after completing the passage, each subject was given five comprehension questions, typed on a single sheet, and asked to "Circle the best answer for each question." Four possible responses appeared for each item.

CHAPTER 3
RESULTS

Overview of the Analysis

This chapter will begin with a description of scoring procedures used with both experimental tasks, the BARF and the Brigance, and a discussion of the interrater reliability associated with these procedures. Descriptive statistics will then be presented to characterize each reading group in terms of both classification variables and dependent measures. Discussion of five separate analyses will follow. These analyses were designed to assess (a) the contribution of between-subjects factors to performance on the BARF and the Brigance, (b) the contribution of within-subject factors to performance on the BARF, (c) the contribution of general scholastic ability to performance on both tasks, (d) the presence of subtypes within this population using cluster analytic techniques, and (e) the presence of subtypes within this population using clinical-inferential techniques.

Analysis of between-subjects factors was performed using multivariate analysis of variance (MANOVA), with error percentage and mean response time as the dependent variables. Two between-subjects factors, Reading Group and Race, were included in the model. Follow-up univariate analyses of variance (ANOVA) were performed for each dependent variable. Tukey's Studentized Range Test was used for

posttest comparison of group means. Separate analyses were performed for each of nine pairs of error percentages and mean response times on the BARF and for error percentage and reading rate on the Brigance. Thus, each pair of dependent variables was treated as an independent task in this analysis. Univariate ANOVAs were also used to analyze the contribution of between-subjects factors to variance in four separate error types. Reading Group and Race were again included in the model and Tukey's test was used for comparison of group means.

Analysis of within-subject factors utilized a multivariate repeated measures ANOVA. This analysis allowed an assessment of performance differences across subtests of the BARF and of Subtest x Reading Group interactions. Subtests were treated as repeated measures rather than independent tasks. Planned comparisons were made across theoretically meaningful groups of subtests and were performed separately for the three types of dependent variables: (a) error percentages, (b) mean response times, and (c) error types. Duncan's Multiple Range Test was used for these comparisons. Race was no longer included in the model since between-subjects analysis had not revealed a significant effect for this factor.

The contribution of general scholastic ability to performance on both experimental tasks was explored with an analysis of covariance. Performance on the Otis-Lennon School Abilities Test was observed to differ across reading groups and was designated the covariate in this analysis. Each of the MANOVAs and ANOVAs from the between-subjects analysis was repeated with the effects of general scholastic ability held constant.

The three analyses described above involve multiple F tests and multiple posttest comparisons of means performed on the same data set. Caution must be exercised in this situation since the performance of multiple tests increases the probability of making a Type I error. Type I error is defined as the rejection of the null hypothesis when it in fact reflects the true state of affairs in the population (Winer, 1971). In order to reduce the probability of this type of error, the alpha level was set conservatively at .01 for all the significance tests performed in this study.

A cluster analytic technique termed FASTCLUS (SAS Institute, Inc., 1985) was employed to search for subtypes in this population. This program is based on a K-means iterative partitioning technique and is useful when specific subtypes are expected based on an explicit theoretical model. Mean profiles of expected clusters can be specified as "seeds" and the program clusters observations around these profiles. Seed profiles were created using a small subset of dependent variables believed to be most predictive of reading mechanism. Five clusters were predicted containing (a) superior readers, (b) normal readers, (c) lexical readers, (d) phonological readers, and (e) readers with deficits in both reading routes. The external validity of the cluster solution was assessed using univariate ANOVA followed by Duncan's tests to compare the Brigance reading rates of the derived clusters.

Finally, a set of classification rules (see Appendix 10) was generated based on the theoretical model of reading disability subtypes developed by Gonzalez-Rothi et al. (1984). Two subtypes were

defined: (a) phonological readers and (b) lexical readers. Subjects who did not meet the criteria for either subtype were placed in an unclassified group. Visual inspection of individual profiles was used to classify each subject. Brigance reading rates were compared across these subgroups as well.

Scoring

Battery of Adult Reading Function

Error percentages were computed for Subtests 1 - 6 and for both Functors and Contentives in Appendix A. Mean response times were computed for each of these tasks, based only on correct trials. The total error rate and total mean response time across all tasks were also calculated. Each error on Subtests 1 - 4 was classified by type based on the taped recording of each subject's responses. Errors could be classified as (a) semantic, (b) phonological, (c) visual, (d) visual-phonological, (e) derivational, or (f) other, according to the criteria described in Appendix 9. The percentage of total errors which fell into each category was computed across all subtests. Ultimately, these six categories were consolidated to form three independent error types. "Phonological" errors included all phonological and visual-phonological errors. "Lexical" errors included all semantic, visual, and derivational errors. Finally, errors which did not meet the criteria for any error type were maintained in the category referred to as "Other." Finally, a lexicalization index was computed. This index reflected the percentage of responses on Subtest 1 which were real words.

Brigance Diagnostic Inventory of Basic Skills

Error percentage, based on five multiple choice questions, and reading rate in words per minute were computed for each subject.

Reliability

Interrater reliability for judgments of response accuracy and error type classification on the BARF was assessed utilizing taped recordings of subject responses. Nine subjects, constituting 10% of the total sample, were randomly selected to assess reliability of response accuracy judgments. Two independent raters achieved 97% agreement in rating responses as correct or incorrect. Percent agreement on individual subtests ranged from 91% on Subtest 1 to 99% on Appendix A. A second sample of protocols was selected to assess the reliability of error type classification judgments. Three subjects were randomly selected from each reading group to form a subset of nine subjects or 10% of the total sample. Selection from each group was employed to maximize the likelihood that a wide variety of error types would be represented. Two independent raters achieved 82% agreement in classifying errors according to the criteria presented in Appendix 9.

Descriptive Statistics

Percentile means and standard deviations for the Metropolitan Achievement Test (1978) and the Otis-Lennon School Abilities Test (1979) are presented for each reading group in Table 1. The racial composition of each reading group is displayed in Table 2. Table 3 contains means and standard deviations of all error percentages on the BARF by reading group. These values are not suggestive of floor or

Table 1
Percentile Means and Standard Deviations by Reading Group for "Metropolitan Achievement Test--Reading" and "Otis-Lennon School Abilities Test"

		Superior	Normal	Impaired
Metropolitan	$\bar{X}$ =	85.47	51.07	20.00
	S.D. =	9.36	5.67	8.76
Otis-Lennon	$\bar{X}$ =	77.13	59.10	34.77
	S.D. =	18.12	20.00	15.52

Table 2
Racial Composition of Reading Groups for "Metropolitan Achievement Test--Reading" and "Otis-Lennon School Abilities Test"

	Superior	Normal	Impaired
Black	7%	33%	57%
White	93%	67%	43%

Table 3
Means and Standard Deviations by Reading Group for "Battery of Adult Reading Function": Error Percentage

		Superior	Normal	Impaired
Total	$\bar{X}$ =	13.33	20.67	34.00
	S.D. =	4.71	8.58	10.53
Subtest 1	$\bar{X}$ =	33.47	39.27	60.77
	S.D. =	13.89	19.73	16.29
Subtest 2	$\bar{X}$ =	4.57	9.17	21.30
	S.D. =	5.35	8.30	15.28
Subtest 3	$\bar{X}$ =	8.27	19.53	35.67
	S.D. =	6.40	11.61	14.14
Subtest 4	$\bar{X}$ =	22.60	40.17	59.30
	S.D. =	11.01	12.83	12.05
Subtest 5	$\bar{X}$ =	14.70	20.33	25.47
	S.D. =	9.34	11.28	15.12
Subtest 6	$\bar{X}$ =	17.07	23.20	38.70
	S.D. =	8.05	14.10	11.68
Appendix A: Functors	$\bar{X}$ =	4.80	7.57	18.93
	S.D. =	8.51	5.78	13.10
Appendix A: Contentives	$\bar{X}$ =	4.67	4.97	11.60
	S.D. =	11.94	6.33	9.01

ceiling effects for accuracy in any of the groups. Comparable data for mean response times on the BARF appear in Table 4. Table 5 contains the means and standard deviations of error types within each reading group. These values represent the percentage of total errors. Finally, means and standard deviations for error percentage and reading rate on the Brigance appear in Table 6.

Assessment of Between-Subjects Factors

Battery of Adult Reading Function

Multivariate Analysis of Variance (MANOVA). A two-factor (Reading Group, Race) MANOVA was performed on nine separate pairs of error percentages and mean response times (Total Performance, Subtests 1 - 6, Appendix A: Functors, and Appendix A: Contentives). Significant MANOVAs appear in Table 7.

Analysis of Variance: Error percentage. Error percentages were analyzed using univariate ANOVA with two between-subjects factors (Reading Group, Race). The results of these analyses revealed highly significant main effects of Reading Group for the following tasks: (a) Total Performance, (b) Subtests 1 - 4 and 6, and (c) Appendix A: Functors. The effect of Reading Group approached significance for Subtest 5 and Appendix A: Contentives. No other significant main effects or interactions were found (see Tables 8 - 16). Thus, impaired readers made significantly more errors than normal and superior readers on all BARF subtests except Subtest 5 and Appendix A: Contentives. Posttest comparison of group means using Tukey's Studentized Range Test appear in Table 17. Significant differences between all three groups were demonstrated for (a) Total Performance,

Table 4
Means and Standard Deviations by Reading Group for "Battery of Adult Reading Function": Mean Response Time

		Superior (secs.)	Normal (secs.)	Impaired (secs.)
Total	$\bar{X}$ =	1.13	1.21	1.69
	S.D. =	0.27	0.20	0.65
Subtest 1	$\bar{X}$ =	1.27	1.33	2.21
	S.D. =	0.34	0.37	1.37
Subtest 2	$\bar{X}$ =	0.84	0.86	1.19
	S.D. =	0.17	0.17	0.65
Subtest 3	$\bar{X}$ =	0.85	0.88	1.26
	S.D. =	0.16	0.16	0.67
Subtest 4	$\bar{X}$ =	0.91	0.93	1.11
	S.D. =	0.21	0.17	0.33
Subtest 5	$\bar{X}$ =	1.41	1.71	2.36
	S.D. =	0.41	0.57	1.02
Subtest 6	$\bar{X}$ =	2.18	2.35	3.41
	S.D. =	0.88	0.84	1.70
Appendix A: Functors	$\bar{X}$ =	0.82	0.83	1.02
	S.D. =	0.17	0.12	0.26
Appendix A: Contentives	$\bar{X}$ =	0.78	0.79	0.96
	S.D. =	0.16	0.12	0.24

Table 5
Means and Standard Deviations by Reading Group for "Battery of Adult Reading Function": Cumulative Percentage of Error Types

		Error Type					
		Semantic	Phono-logic	Visual	Visual/Phono-logical	Deriva-tional	Other
Superior	$\bar{X}$ =	0.23	0.37	5.10	92.30	1.90	0.10
	S.D. =	0.90	1.13	5.23	6.31	2.81	0.55
Normal	$\bar{X}$ =	0.20	0.67	6.53	88.80	3.33	0.47
	S.D. =	0.61	1.58	4.99	7.09	4.10	1.01
Impaired	$\bar{X}$ =	0.30	0.77	15.70	77.97	3.37	1.53
	S.D. =	0.65	1.25	10.91	13.12	2.66	1.87

Table 6
Means and Standard Deviations by Reading Group for "Brigance Diagnostic Inventory of Basic Skills": Error Percentage and Reading Rate

		Superior	Normal	Impaired
Error %	$\bar{X}$ =	17.33	29.33	27.33
	S.D. =	16.39	25.59	27.53
Reading Rate (words per minutes)	$\bar{X}$ =	187.03	148.93	112.63
	S.D. =	54.47	38.01	41.84

Table 7
Analysis of Between-Subjects Factors for "Battery of Adult Reading Function": Significant MANOVAs

Total Performance	READING GROUP	$F(4,164) = 13.96$	$p = .0001$
Subtest 1	READING GROUP	$F(4,164) = 9.39$	$p = .0001$
Subtest 2	READING GROUP	$F(4,164) = 6.97$	$p = .0001$
Subtest 3	READING GROUP	$F(4,164) = 14.29$	$p = .0001$
Subtest 4	READING GROUP	$F(4,164) = 16.28$	$p = .0001$
Subtest 5	READING GROUP	$F(4,164) = 4.91$	$p = .0009$
Subtest 6	READING GROUP	$F(4,164) = 11.37$	$p = .0001$
Appendix A: Functors	READING GROUP	$F(4,164) = 6.85$	$p = .0001$
Appendix A: Contentives	READING GROUP	$F(4,164) = 4.70$	$p = .0013$

Table 8
Univariate ANOVA: Error Percentage for "Battery of Adult Reading Function": Total Performance

Source	DF	SS	F	PR > F
GROUP	2	3863.33	27.30	0.0001
RACE	1	5.15	0.07	0.7879
GROUP*RACE	2	20.19	0.14	0.8673

Table 9
Univariate ANOVA: Error Percentage for "Battery of Adult Reading Function": Subtest 1

Source	DF	SS	F	PR > F
GROUP	2	8977.74	15.75	0.0001
RACE	1	113.52	0.40	0.5297
GROUP*RACE	2	458.54	0.80	0.4509

Table 10
Univariate ANOVA: Error Percentage for "Battery of Adult Reading Function": Subtest 2

Source	DF	SS	F	PR > F
GROUP	2	3067.16	13.49	0.0001
RACE	1	7.82	0.07	0.7937
GROUP*RACE	2	49.41	0.22	0.8051

Table 11
Univariate ANOVA: Error Percentage for "Battery of Adult Reading Function": Subtest 3

Source	DF	SS	F	PR > F
GROUP	2	7107.45	27.74	0.0001
RACE	1	129.40	1.01	0.3178
GROUP*RACE	2	18.30	0.07	0.9311

Table 12
Univariate ANOVA: Error Percentage for "Battery of Adult Reading Function": Subtest 4

Source	DF	SS	F	PR > F
GROUP	2	9295.02	31.42	0.0001
RACE	1	32.92	0.22	0.6383
GROUP*RACE	2	74.25	0.25	0.7786

Table 13
Univariate ANOVA: Error Percentage for "Battery of Adult Reading Function": Subtest 5

Source	DF	SS	F	PR > F
GROUP	2	693.06	2.42	0.0953
RACE	1	16.41	0.11	0.7359
GROUP*RACE	2	508.20	1.77	0.1762

Table 14
Univariate ANOVA: Error Percentage for "Battery of Adult Reading Function": Subtest 6

Source	DF	SS	F	PR > F
GROUP	2	4481.92	16.39	0.0001
RACE	1	8.82	0.06	0.8001
GROUP*RACE	2	117.47	0.43	0.6522

Table 15
Univariate ANOVA: Error Percentage for "Battery of Adult Reading Function": Functors

Source	DF	SS	F	PR > F
GROUP	2	2217.57	11.63	0.0001
RACE	1	4.92	0.05	0.8208
GROUP*RACE	2	32.69	0.17	0.8427

Table 16
Univariate ANOVA: Error Percentage for "Battery of Adult Reading Function": Contentives

Source	DF	SS	F	PR > F
GROUP	2	797.97	4.40	0.0152
RACE	1	10.23	0.11	0.7379
GROUP*RACE	2	34.96	0.19	0.8250

Table 17
Tukey's Studentized Range Test: Error Percentage for "Battery of Adult Reading Function"

	Reading Group		
	Impaired	Normal	Superior
Total Performance Error %	34.00	20.67	13.33
Subtest 1 Error %	60.77	39.27	33.47
Subtest 2 Error %	21.30	9.17	4.57
Subtest 3 Error %	35.67	19.53	8.27
Subtest 4 Error %	59.30	40.17	22.60
Subtest 6 Error %	38.70	23.20	17.07
Appendix A: Functors Error %	18.93	7.57	4.80

(b) Subtest 3, and (c) Subtest 4. On Subtests 1, 2, and 6 and Appendix A: Functors, impaired readers made more errors than normal and superior readers. The error percentages of normal and superior readers were not significantly different.

Analysis of Variance: Mean response time. Mean response times were analyzed using univariate ANOVA with two between-subjects factors (Reading Group, Race). The results of these analyses revealed highly significant main effects of Reading Group for the following tasks: (a) Total Performance; (b) Subtests 1-3, 5, and 6; (c) Appendix A: Functors; and (d) Appendix A: Contentives. The effect of Reading Group approached significance for Subtest 4. No other significant main effects or interactions were found (see Tables 18 - 26). Thus, impaired readers had significantly slower response times than normal and superior readers on all BARF subtests except Subtest 4. Posttest comparisons of group means using Tukey's Studentized Range Test appear in Table 27. On all subtests, impaired readers performed more slowly than both normal and superior readers who did not differ from each other.

Analysis of Variance: Error type. Four error type variables were analyzed using univariate ANOVA with two between-subjects factors (Reading Group, Race): (a) Phonological errors, (b) Lexical errors, (c) Other errors, and (d) the Lexicalization Index. Results revealed highly significant main effects of Reading Group for Phonological, Lexical, and Other errors (see Tables 28 - 30). The Lexicalization Index did not significantly differ as a function of Reading Group (see Table 31). No other significant main effects or interactions were

Table 18
Univariate ANOVA: Mean Response Time for "Battery of Adult Reading Function": Total Performance

Source	DF	SS	F	PR > F
GROUP	2	3.74	10.22	0.0001
RACE	1	0.02	0.12	0.7309
GROUP*RACE	2	0.03	0.07	0.9319

Table 19
Univariate ANOVA: Mean Response Time for "Battery of Adult Reading Function": Subtest 1

Source	DF	SS	F	PR > F
GROUP	2	11.79	8.50	0.0004
RACE	1	0.40	0.58	0.4494
GROUP*RACE	2	2.86	2.06	0.1334

Table 20
Univariate ANOVA: Mean Response Time for "Battery of Adult Reading Function": Subtest 2

Source	DF	SS	F	PR > F
GROUP	2	1.67	5.17	0.0077
RACE	1	0.05	0.29	0.5902
GROUP*RACE	2	0.27	0.84	0.4343

Table 21
Univariate ANOVA: Mean Response Time for "Battery of Adult Reading Function": Subtest 3

Source	DF	SS	F	PR > F
GROUP	2	2.31	6.71	0.0020
RACE	1	0.02	0.12	0.7336
GROUP*RACE	2	0.06	0.19	0.8290

Table 22
Univariate ANOVA: Mean Response Time for "Battery of Adult Reading Function": Subtest 4

Source	DF	SS	F	PR > F
GROUP	2	0.52	4.29	0.0168
RACE	1	0.00	0.00	0.9545
GROUP*RACE	2	0.03	0.25	0.7785

Table 23
Univariate ANOVA: Mean Response Time for "Battery of Adult Reading Function": Subtest 5

Source	DF	SS	F	PR > F
GROUP	2	8.34	7.93	0.0007
RACE	1	0.00	0.01	0.9208
GROUP*RACE	2	0.09	0.09	0.9174

Table 24
Univariate ANOVA: Mean Response Time for "Battery of Adult Reading Function": Subtest 6

Source	DF	SS	F	PR > F
GROUP	2	19.16	6.39	0.0026
RACE	1	0.00	0.00	0.9628
GROUP*RACE	2	0.81	0.27	0.7631

Table 25
Univariate ANOVA: Mean Response Time for "Battery of Adult Reading Function": Functors

Source	DF	SS	F	PR > F
GROUP	2	0.57	7.57	0.0009
RACE	1	0.17	0.45	0.5054
GROUP*RACE	2	0.07	0.93	0.3977

Table 26

Univariate ANOVA: Mean Response Time for "Battery of Adult Reading Function": Contentives

Source	DF	SS	F	PR > F
GROUP	2	0.43	6.88	0.0017
RACE	1	0.00	0.02	0.8819
GROUP*RACE	2	0.09	1.39	0.2556

Table 27
Tukey's Studentized Range Test: Mean Response Time for "Battery of Adult Reading Function"

	Reading Group		
	Impaired	Normal	Superior
Total Performance RT (secs.)	1.69	1.21	1.13
Subtest 1 RT (secs.)	2.21	1.33	1.27
Subtest 2 RT (secs.)	1.19	0.86	0.84
Subtest 3 RT (secs.)	1.26	0.88	0.85
Subtest 5 RT (secs.)	2.36	1.71	1.41
Subtest 6 RT (secs.)	3.41	2.35	2.19
Appendix A: Functors RT (secs.)	1.02	0.83	0.82
Appendix A: Contentives RT (secs.)	0.95	0.79	0.77

Table 28
Univariate ANOVA: Error Type for "Battery of Adult Reading Function": Phonological Errors

Source	DF	SS	F	PR > F
GROUP	2	2181.94	12.64	0.0001
RACE	1	2.90	0.03	0.8549
GROUP*RACE	2	34.59	0.20	0.8188

Table 29
Univariate ANOVA: Error Type for "Battery of Adult Reading Function": Lexical Errors

Source	DF	SS	F	PR > F
GROUP	2	1774.14	11.58	0.0001
RACE	1	3.79	0.05	0.8246
GROUP*RACE	2	32.03	0.21	0.8117

Table 30
Univariate ANOVA: Error Type for "Battery of Adult Reading Function": Other Errors

Source	DF	SS	F	PR > F
GROUP	2	21.09	6.36	0.0027
RACE	1	0.06	0.04	0.8512
GROUP*RACE	2	0.14	0.04	0.9593

Table 31
Univariate ANOVA: Error Type for "Battery of Adult Reading Function": Lexicalization Index

Source	DF	SS	F	PR > F
GROUP	2	950.97	2.03	0.1377
RACE	1	0.03	0.00	0.9917
GROUP*RACE	2	141.72	0.30	0.7397

found. Posttest comparisons of group means using Tukey's Studentized Range Test appear in Table 32. Impaired readers made significantly fewer Phonological errors than normal and superior readers who did not differ from each other. Impaired readers made significantly more Lexical and Other errors than normal and superior readers, who again were not significantly different.

Brigance Diagnostic Inventory of Basic Skills

Multivariate Analysis of Variance (MANOVA). A two-factor (Reading Group, Race) MANOVA was performed with error percentage and reading rate as the dependent variables. The main effect of Reading Group was highly significant ($F(4,164) = 6.10$, $p=.0001$). No other multivariate analyses were significant.

Analysis of Variance: Error percentage. Error percentage was analyzed using univariate ANOVA with two between-subjects factors (Reading Group, Race). No significant main effects or interactions were found (see Table 33). Thus, error percentage on the *Brigance* was unrelated to either reading group membership or race.

Analysis of Variance: Reading rate. Reading rates were analyzed using univariate ANOVA with two between-subjects factors (Reading Group, Race). The results of this analysis revealed a highly significant main effect of Reading Group. No other significant main effects or interactions were found (see Table 34). Posttest comparisons of group means using Tukey's Studentized Range Test appear in Table 35. Superior readers had significantly faster reading rates than normals who had significantly faster rates than impaired readers.

Table 32
Tukey's Studentized Range Test: Error Type for "Battery of Adult Reading Function"

	Reading Group		
	Impaired	Normal	Superior
Phonological % Total Errors	78.73	89.47	92.67
Lexical % Total Errors	19.73	10.07	7.23
Other % Total Errors	1.53	0.47	0.10

Table 33
Univariate ANOVA: Error Percentage for "Brigance Diagnostic Inventory of Basic Skills"

Source	DF	SS	F	PR > F
GROUP	2	847.73	0.74	0.4794
RACE	1	367.23	0.64	0.4250
GROUP*RACE	2	32.97	0.03	0.9716

Table 34
Univariate ANOVA: Reading Rate for "Brigance Diagnostic Inventory of Basic Skills"

Source	DF	SS	F	PR > F
GROUP	2	46770.70	11.04	0.0001
RACE	1	621.95	0.29	0.5894
GROUP*RACE	2	461.84	0.11	0.8969

Table 35
Tukey's Studentized Range Test: Reading Rate for "Brigance Diagnostic Inventory of Basic Skills"

	Reading Group		
	Impaired	Normal	Superior
Reading Rate (words per minute)	112.63	148.93	187.03

Assessment of Within-Subject Factors

In this analysis, BARF subtests were treated as repeated measures rather than as independent tasks. Repeated measures ANOVAs with one between-subjects factor (Reading Group) and one within-subject factor (Subtest) were performed. Race was dropped from the model due to the nonsignificant findings in the between-subjects analysis. Three sets of planned comparisons were made within theoretically related groups of subtests. Comparisons were made between (a) Subtests 1 - 4, (b) Subtests 5 and 6, and (c) Appendix A: Functors and Appendix A: Contentives. Separate analyses of error percentage, mean response time, and error type data will be presented. Since the between-subjects effects of Reading Group were discussed above, only within-subject main effects and interactions will be reported here.

Error percentage. Repeated measures ANOVA on Subtests 1 - 4 produced a significant main effect of Subtest, as well as a significant Reading Group x Subtest interaction (see Table 36). Results of Duncan's Multiple Range Test, performed on subtest means by reading group, appear in Table 39. In both normal and impaired readers, fewest errors occurred on Subtest 2 (regular words), followed by Subtest 3 (rule governed words), with highest error rates on Subtests 1 (nonwords) and 4 (irregular words). Significant differences were revealed between all subtests except 1 and 4. However, superior readers poorest performance was on Subtest 1 (nonwords) followed by 4 (irregular), 3 (rule governed), and

Table 36
Repeated Measures ANOVA: Error Percentage for "Battery of Adult Reading Function": Subtests 1-4, Within-Subject Effects

Source	DF	SS	F	PR > F
SUBTEST	3	66370.72	328.88	0.0
SUBTEST*GROUP	6	3542.86	8.78	0.0001

Table 37
Repeated Measures ANOVA: Error Percentage for "Battery of Adult Reading Function": Subtests 5-6, Within-Subject Effects

Source	DF	SS	F	PR > F
SUBTEST	1	1705.09	15.30	0.0002
SUBTEST*GROUP	2	1129.01	5.07	0.0083

Table 38
Repeated Measures ANOVA: Error Percentage for "Battery of Adult Reading Function": Functors/Contentives, Within-Subject Effects

Source	DF	SS	F	PR > F
SUBTEST	1	506.69	17.17	0.0001
SUBTEST*GROUP	2	401.64	6.80	0.0018

2 (regular). The difference between Subtests 3 and 2 was not significant.

Analysis of Subtests 5 and 6 showed a significant main effect of Subtest as well as a significant Reading Group x Subtest interaction (see Table 37). Table 40 displays the results of Duncan's test on subtest means, by reading group. Error rates of normal and superior readers on Subtests 5 and 6 were not significantly different. Impaired readers made significantly more errors on Subtest 6, which requires a phonological reading route, compared to Subtest 5 which requires lexical reading.

Finally, a significant Subtest effect and Subtest x Group interaction were also shown in the analysis of Functors and Contentives (see Table 38). Results of Duncan's test again showed that normal and superior readers perform similarly with these two word classes while impaired readers have significantly more difficulty with functors.

Mean response time. Repeated measures ANOVA on Subtests 1 - 4 produced a significant main effect of Subtest and a significant Reading Group x Subtest interaction (see Table 42). Results of Duncan's Multiple Range Test, performed on subtest means by Reading Group, appear in Table 45. In all three reading groups, significantly slower response times occurred on Subtest 1 (nonwords). Response times to Subtests 2 (regular words), 3 (rule governed words), and 4 (irregular words) were not significantly different. However, impaired readers differed from the other two groups by a nonsignificant tendency to response more quickly to Subtest 4 (irregular words).

Table 39
Duncan's Multiple Range Test: Error Percentage for "Battery of Adult Reading Function": Subtests 1-4

		Subtest			
Group		1	2	3	4
Impaired	Error %	60.77	21.30	35.67	59.30
Normal	Error %	39.27	9.17	19.53	40.17
Superior	Error %	33.47	4.57	8.27	22.60

Table 40
Duncan's Multiple Range Test: Error Percentage for "Battery of Adult Reading Function": Subtests 5-6

		Subtest	
Group		5	6
Impaired	Error %	25.47	38.70
Normal	Error %	20.33	23.20
Superior	Error %	14.70	17.07

Table 41
Duncan's Multiple Range Test: Error Percentage for "Battery of Adult Reading Function": Functors/Contentives

		Subtest	
Group		Functors	Contentives
Impaired	Error %	18.93	11.60
Normal	Error %	7.57	4.97
Superior	Error %	4.80	4.67

Table 42
Repeated Measures ANOVA: Mean Response Time for "Battery of Adult Reading Function": Subtests 1-4, Within-Subject Effects

Source	DF	SS	F	PR > F
SUBTEST	3	26.21	66.87	0.0001
SUBTEST*GROUP	6	5.91	7.54	0.0001

Normal and superior readers tended to respond more quickly on Subtest 2 (regular words).

Analysis of Subtests 5 and 6 showed a significant main effect of Subtest (see Table 43). Table 46 displays the results of Duncan's test on subtest means, by reading group. In all readers, slower response times occurred on Subtest 6, which requires phonological reading, compared to Subtest 5 which requires the lexical route.

A significant main effect of Subtest was also shown in the analysis of Functors and Contentives (see Table 44). Results of Duncan's test showed that all subjects had slower response times to Functors, as compared to Contentives.

Error type. Repeated measures ANOVA was also used to explore within-subject effects on the occurrence of three types of errors: (a) Phonological errors, (b) Lexical errors, and (c) Other errors. The analysis was performed with Reading Group as the between-subjects factor and Error Type as the within-subject factor. A significant main effect for Error Type and a significant Reading Group x Error Type interaction was found (see Table 48). The results of Duncan's Multiple Range Test appear in Table 49. Phonological errors were the most frequent error type, followed by Lexical errors, with Other errors the least frequent in all reading groups. However, both Lexical and Other errors made up a larger percentage of the total errors made by impaired readers.

Assessment of the Contribution of General Scholastic Ability

Inspection of group means revealed substantial differences between reading groups on the Otis-Lennon School Abilities Test

Table 43

Repeated Measures ANOVA: Mean Response Time for "Battery of Adult Reading Function": Subtests 5-6, Within-Subject Effects

Source	DF	SS	F	PR > F
SUBTEST	1	30.68	53.26	0.0001
SUBTEST*GROUP	2	1.32	1.15	0.3217

Table 44

Repeated Measures ANOVA: Mean Response Time for "Battery of Adult Reading Function": Functors/Contentives, Within-Subject Effects

Source	DF	SS	F	PR > F
SUBTEST	1	0.10	30.14	0.0001
SUBTEST*GROUP	2	0.01	1.46	0.2367

Table 45
Duncan's Multiple Range Test: Mean Response Time for "Battery of Adult Reading Function": Subtests 1-4

		Subtest			
Group		1	2	3	4
Impaired	RT (secs.)	2.21	1.19	1.26	1.11
Normal	RT (secs.)	1.33	0.86	0.88	0.93
Superior	RT (secs.)	1.27	0.84	0.85	0.91

Table 46
Duncan's Multiple Range Test: Mean Response Time for "Battery of Adult Reading Function": Subtests 5-6

	Subtest	
	5	6
RT (secs.)	1.83	2.65

Table 47
Duncan's Multiple Range Test: Mean Response Time for "Battery of Adult Reading Function": Functors/Contentives

	Subtest	
	Functors	Contentives
RT (secs.)	0.89	0.84

Table 48
Repeated Measures ANOVA: Error Type for "Battery of Adult Reading Function": Phonological, Lexical and Other for Within-Subject Effects

Source	DF	SS	F	PR > F
ETYPE	2	394272.96	2469.04	0.0
ETYPE*GROUP	4	5806.31	18.18	0.0001

Table 49
Duncan's Multiple Range Test: Error Type for "Battery for Adult Reading Function": Phonological, Lexical, and Other

	Error Type		
Group	Phonological	Lexical	Other
Impaired			
ET (% Total E)	78.74	19.73	1.53
Normal			
ET (% Total E)	89.46	10.07	0.47
Superior			
ET (% Total E)	92.67	7.23	0.10

(Otis-Lennon) (1979). These differences in general scholastic ability might account for the significant group differences in performance on the BARF and the Brigance. In order to rule out this possibility, score on the Otis-Lennon was designated the covariate in an analysis of covariance. Each of the MANOVAs and ANOVAs from the between-subjects analysis was repeated, including Otis-Lennon score as a between-subjects factor. Error percentage and mean response time were the dependent variables in the MANOVAs. Follow-up ANOVAs were performed for each dependent variable in isolation. Univariate ANOVAs were performed for each error type. Follow-up comparisons of least squared means tested the hypothesis of no Reading Group or Race differences, with Otis-Lennon score held constant at its mean value.

Battery of Adult Reading Function

Multivariate Analysis of Variance (MANOVA). A three-factor (Otis-Lennon, Reading Group, Race) MANOVA was performed on nine separate pairs of error percentages and mean response times (Total Performance, Subtests 1 - 6, Appendix A: Functors, and Appendix A: Contentives). Only one of these MANOVAs was significant. For Subtest 5, the main effect of Otis-Lennon score was highly significant ($F(2,82) = 8.44$, $p=.0005$). No other multivariate analyses were significant.

Analysis of Variance: Error percentage. Error percentage was analyzed using univariate ANOVA with three between-subjects factors (Otis-Lennon, Reading Group, Race). The only significant main effect was for Otis-Lennon score on Subtest 5 which requires a lexical reading route (see Table 50). Results of the least squared means

Table 50

Analysis of Covariance: Error Percentage for "Battery of Adult Reading Function": Subtest 5 with Covariate = "Otis-Lennon School Abilities Test"

Source	DF	SS	F	PR > F
OTIS	1	2009.39	16.62	0.0001
GROUP	2	41.04	0.17	0.8442
RACE	1	20.40	0.17	0.6822
GROUP*RACE	2	546.40	2.26	0.1107

Least Squares Means

Prob > t	H_0: LSMEAN(i) = LSMEAN(j)		
i/j	1	2	3
1	.	0.8759	0.6014
2	0.8759	.	0.5720
3	0.6014	0.5720	.

1 = Normal readers 2 = Impaired readers 3 = Superior readers

procedure showed that the differences between reading groups on this measure could be accounted for by group differences in performance on the Otis-Lennon (see Table 50).

Analysis of Variance: Mean response time. Mean response times were analyzed using univariate ANOVA with three between-subjects factors (Otis-Lennon, Reading Group, Race). No significant main effects or interactions involving the Otis-Lennon factor were found in the analysis of response times. The significant main effect of Reading Group was maintained.

Analysis of Variance: Error type. Four error type variables were analyzed using univariate ANOVA with three between-subjects factors (Otis-Lennon, Reading Group, Race): (a) Phonological errors, (b) Lexical errors, (c) Other errors, and (d) the Lexicalization Index. Otis-Lennon score was not involved in any significant main effects or interactions for any of the four error types. The significant main effect of Reading Group for Phonological, Lexical, and Other errors was maintained.

Brigance Diagnostic Inventory of Basic Skills

Multivariate Analysis of Variance (MANOVA). A three-factor (Otis-Lennon, Reading Group, Race) MANOVA was performed with error percentage and reading rate as the dependent variables. Results of this analysis revealed no significant main effects or interactions involving the Otis-Lennon factor.

Analysis of Variance: Error percentage. Error percentage was analyzed using univariate ANOVA with three between-subjects factors

(Otis-Lennon, Reading Group, Race). No significant main effects or interactions involving Otis-Lennon score occurred.

Analysis of Variance: Reading rate. Reading rates were analyzed using univariate ANOVA with three between-subjects factors (Otis-Lennon, Reading Group, Race). No significant main effects or interactions involving Otis-Lennon score occurred. The significant main effect of Reading Group was maintained.

Subtype Identification: Multivariate Statistical

The FASTCLUS program (SAS Institute, Inc., 1985) was chosen to search for subtypes in this population. This technique performs a disjoint cluster analysis on the basis of Euclidean distances computed from one or more quantitative variables. Observations are divided such that every observation belongs to one and only one cluster. This procedure is based on a method referred to as nearest centroid sorting. A set of point called cluster seeds is chosen to serve as initial guesses about the mean cluster profiles. Each observation is assigned to the nearest seed to form temporary clusters. The seeds are then replaced by the means of these temporary clusters and the matching process is repeated. This sequence is repeated until no further changes occur in the cluster solution. This method is most appropriate when specific subtypes are predicted based on an explicit theoretical model.

It was necessary to select a small subset of the many dependent variables assessed in this study to be entered into the clustering algorithm. Initially, six dependent variables were chosen, based on

their presumed predictive utility in differentiating phonological and lexical reading mechanisms. Two of these variables were newly created for this analysis. The first was termed HOMO and was defined as Error % on Subtest 5 minus Error % on Subtest 6. This variable reflected the difference in performance on a measure of lexical reading (Subtest 5) relative to a measure of phonological reading (Subtest 6). The second new variable was referred to as FCDIFF and was defined as Error % on Functors minus Error % on Contentives. Four other previously discussed dependent variables were selected: (a) Error % on Subtest 1 (EP1), (b) Error % on Subtest 4 (EP4), (c) the Lexicalization Index (WORD1), and (d) Lexical errors (LEXERR).

The initial set of six variables was examined further to assess their appropriateness for this analysis. The frequency distribution of each variable was visually inspected. Only one variable, LEXERR appeared to have a markedly deviant distribution. Secondly, intercorrelation matrices were generated, separately for each reading group, to determine the amount of redundancy contained in this set of variables. In both impaired and normal readers, EP1, EP4, and LEXERR were highly correlated. In superior readers, EP1 and EP4 were highly correlated.

A decision was made to drop LEXERR from the set of clustering variables. This removed the only variable with a deviant frequency distribution, eliminating the need to standardize the variables before clustering. One pair of highly correlated variables remained, EP1 and EP4. However, neither of these was removed from the set due to their presumed importance for subtype identification.

Five clusters were predicted containing (a) Superior readers, (b) Normal readers, (c) Lexical readers, (d) Phonological readers, and (e) readers with deficits in both reading routes. Mean profiles for each of these predicted clusters across the five clustering variables appear in Table 51. These seeds were generated based on the <u>BARF</u> profiles predicted for phonological and lexical readers (Gonzalez-Rothi et al., 1984). Superior and Normal readers should (a) perform equally on Subtests 1 and 4, (b) have a relatively low percentage of lexicalizations, and (c) perform equally on Subtests 5 and 6 and on Functors and Contentives. These two groups will differ only quantitatively, with Superior readers making fewer errors. Lexical and Phonological readers will make more errors than Normal readers but will not differ quantitatively from each other. Lexical readers will (a) make more errors on Subtest 1 relative to Subtest 4, (b) have a larger percentage of lexicalizations, (c) make more errors on Subtest 6 than Subtest 5, and (d) make more errors on Functors than on Contentives. Phonological readers will (a) make more errors on Subtest 4 than Subtest 1, (b) have a relatively low percentage of lexicalizations, (c) make more errors on Subtest 5 than Subtest 6, and (d) perform equally on Functors and Contentives. Finally, mixed deficits readers will make more errors than all other clusters. These readers will (a) perform equally on Subtests 1 and 4, (b) have a relatively high percentage of lexicalizations, and (c) perform equally on Subtests 5 and 6 and on Functors and Contentives.

Table 51
Initial Seeds: FASTCLUS Procedure

Cluster	Name	EP1(%)	EP4(%)	WORD1(%)	HOMO(%)	FCDIFF(%)
1	Superior	10	10	25	0	0
2	Normal	20	20	25	0	0
3	Lexical	60	30	50	-20	20
4	Phonological	30	60	25	20	0
5	Mixed Deficits	60	60	50	0	0

A summary of the cluster solution appears in Table 52. The following frequencies were obtained: (a) Superior = 9, (b) Normal = 31, (c) Lexical = 13, (d) Phonological = 17, and (e) Mixed Deficits = 20. Although the distance between cluster means (or centroids) was considerably larger than the standard deviation of distances within a cluster, each cluster had at least one member that was farther away from its mean than the centroid distance.

Cluster means and standard deviations appear in Table 53. Although in most cases, the general shape and relative elevation of the seed profile was maintained, some significant changes were noted:

1. Superior readers had a much smaller percentage of lexicalizations than Normal readers.
2. The profile of Lexical readers no longer showed differential performance on Subtests 1 and 4 and the percentage of lexicalizations was much lower than predicted.
3. Mixed Deficits readers made more errors on Subtest 6 relative to Subtest 5 and had greater difficulty with Functors relative to Contentives than was predicted.
4. The performance of Lexical readers differed quantitatively from that of Phonological readers, with more errors occurring in the Lexical group.

Finally, the distribution of reading groups placed in each cluster appears in Table 54. The majority of Superior readers were placed in either the Superior or Normal cluster. However, a small number of Superior readers appeared in the Phonological cluster. Over

Table 52
Cluster Summary: FASTCLUS Procedure

Cluster	Name	Freq.	RMS S.D.*	Max. Distance from Seed to Observation	Nearest Cluster	Centroid Distance**
1	Superior	9	8.72	31.03	2	29.74
2	Normal	31	10.44	44.43	4	25.65
3	Lexical	13	10.58	36.31	5	31.58
4	Phonological	17	10.59	34.97	2	25.65
5	Mixed Deficits	20	11.84	38.08	3	31.58

* The root-mean-square distance between observations in the cluster.

** The distance between the means of the current cluster and the nearest other cluster.

Table 53
Cluster Means and Standard Deviations, FASTCLUS Procedure

Cluster	Name		EP1(%)	EP4(%)	WORD1(%)	HOMO(%)	FCDIFF(%)
1	Superior						
		$\bar{X}$ =	23.00	17.67	4.89	-5.33	4.33
		S.D. =	10.01	8.46	5.97	8.17	10.30
2	Normal						
		$\bar{X}$ =	34.03	25.65	30.84	-5.16	-0.71
		S.D. =	13.50	9.73	12.55	8.03	6.79
3	Lexical						
		$\bar{X}$ =	52.85	53.62	26.31	-28.62	6.00
		S.D. =	8.15	12.96	11.95	12.70	4.64
4	Phonological						
		$\bar{X}$ =	36.00	43.47	30.53	12.53	4.12
		S.D. =	13.27	10.10	12.60	9.77	5.37
5	Mixed Deficits						
		$\bar{X}$ =	72.20	63.60	38.60	-9.35	6.85
		S.D. =	10.45	7.49	16.33	12.52	10.57

Table 54
Cluster Membership by Reading Group

Cluster 1: Superior = 9	
Reading Group	Superior = 7
	Normal = 2
Cluster 2: Normal = 31	
Reading Group	Superior = 18
	Normal = 11
	Impaired = 2
Cluster 3: Lexical = 13	
Reading Group	Superior = 1
	Normal = 4
	Impaired = 8
Cluster 4: Phonological = 17	
Reading Group	Superior = 4
	Normal = 9
	Impaired = 4
Cluster 5: Mixed Deficits = 20	
Reading Group	Normal = 4
	Impaired = 16

half of Normal readers did not appear in either the Superior or Normal cluster and almost one-third of Normal readers were classified as Phonological readers. Approximately 50% of impaired readers were placed in the Mixed Deficits cluster. Impaired readers were also represented in both the Lexical and Phonological clusters. The ratio of Lexical to Phonological impaired readers was 2:1. The two impaired readers with the highest reading achievement scores appeared in the Normal cluster.

Brigance reading rate was employed to assess the external validity of the clusters with a variable that did not enter into their derivation. Lexical reading is believed to be based on simultaneous processing, while phonological decoding of words requires sequential processing. Thus, phonological and lexical reading routes should differ in processing speed, i.e., lexical processing should occur more rapidly than phonological processing.

Univariate ANOVA with one between-subjects factor (Cluster) was used to analyze *Brigance* reading rates. A highly significant main effect of Cluster emerged (see Table 55). Posttest comparisons of Cluster means using Duncan's Multiple Range Test also appear in Table 55. Although Lexical readers read more rapidly than Phonological readers, this difference was not significant. However, the reading rate of Lexical readers was significantly faster than that of Mixed Deficits readers.

Subtype Identification: Clinical-Inferential

Visual inspection techniques were used to classify subjects into lexical and phonological readers, based on a set of classification

Table 55
Univariate ANOVA: Reading Rate for "Brigance Diagnostic Inventory of Basic Skills"--Comparison of Statistically Generated Clusters

Source	DF	SS	F	PR > F
CLUSTER	4	83121.90	10.52	0.0001

Duncan's Multiple Range Test

Cluster	Superior 1	Normal 2	Lexical 3	Phonological 4	Mixed Deficits 5
Reading Rate (words per minute)	218.60	182.96	150.93	136.94	112.71

rules (see Appendix 10). Subjects who did not meet the criteria for either subtype were placed in an unclassified group. Those subjects who met all the criteria for a given subtype with only one exception are designated in the categories, (Lexical) and (Phonological). The number of subjects placed in each subtype is presented separately for each reading group in Table 56.

Eighty-six percent of Superior readers could not be classified as relying on either reading route. Equal percentages (7%) of Superior readers were placed in the (Phonological) and (Lexical) groups. Just over half of Normal readers could not be classified (57%). Again, roughly equal percentages of Normal readers were placed in the two subtypes (L/(L) = 23%; (P) = 20%). The majority of impaired readers were placed in the two Lexical groups (53%). Forty percent of impaired readers were unclassified and only 7% were classified as Phonological readers.

The Brigance reading rates of the Lexical/(Lexical) and the (Phonological) groups were compared, as was done for the statistically derived clusters. It was hypothesized that slower reading rates would be associated with the phonological reading route. The mean reading rate of Lexical/(Lexical) readers was 124.56 words per minute (WPM) as compared to 132.90 WPM for Phonological readers. The racial distribution of subtypes was also compared within the impaired reading group. The racial distribution of the Lexical/(Lexical) group was not different from that of the combined (Phonological) and Unclassified groups.

Table 56
Clusters Derived by Clinical-Inferential Classification Rules

Superior Readers		
Lexical = 0(0%)	Phonological = 0 (0%)	Unclassified = 26(86%)
(Lexical) = 2(7%)	(Phonological) = 2 (7%)	
Normal Readers		
Lexical = 1 (3%)	Phonological = 0 (0%)	Unclassified = 17(57%)
(Lexical) = 6(20%)	(Phonological) = 6(20%)	
Impaired Readers		
Lexical = 4(14%)	Phonological = 0 (0%)	Unclassified = 12(40%)
(Lexical) = 12(39%)	(Phonological) = 2 (7%)	

CHAPTER 4
DISCUSSION

General Hypothesis 1

It was hypothesized that impaired, normal, and superior readers would exhibit different patterns of performance on the Battery of Adult Reading Function (BARF) (Gonzalez-Rothi et al., 1984). The BARF assesses the recognition and pronounciation of single words, presented in isolation. Subjects had initially been classified as impaired, normal, and superior readers based on their performance on the Metropolitan Achievement Test (1978), a measure which predominantly assesses silent reading comprehension. These two tests emphasize different aspects of reading behavior. However, it is likely that the recognition of single words and the comprehension of printed text are highly related. Thus, quantitative performance differences between subjects on the Metropolitan Achievement Test (1978) should also be present on the BARF. Three specific predictions were made regarding these group differences. Each prediction will be discussed independently in the following sections.

Specific Prediction 1

If word recognition and text comprehension are related processes, then readers who are impaired on the Metropolitan Achievement Test should also be impaired on the BARF relative to normal and superior readers. The BARF performance was characterized by two dependent

variables, error percentage and mean response time. Thus, impairment on this task could be reflected in either increased errors, increased response latencies, or both. It was predicted that impaired readers would make more errors and have slower response times on this test when compared to normal and superior readers.

This prediction received strong support. Impaired readers made significantly more errors than normal and superior readers on the BARF as a whole and also on the majority of individual BARF subtests. Only Subtest 5 and the Contentives portion of Appendix A were not significantly different across groups; however, these nonsignificant differences were in the predicted direction. Response latency was shown to be equally effective in discriminating between reading groups. Impaired readers responded more slowly than normal and superior readers on the BARF as a whole and on all subtests except Subtest 4. Again, this nonsignificant difference was in the expected direction.

It is difficult to account for the failure to achieve significance on specific subtests. It cannot be accounted for by between-subtest differences in word frequency or number of graphemes since these were carefully balanced. One possibility involves the contribution of other cognitive skills to performance on individual subtests. Analysis of covariance revealed that group differences on Subtest 5 could be accounted for by differences in general scholastic ability. The ability to distinguish homophones measured by Subtest 5 may rely heavily on other nonreading skills. However, the other nonsignificant findings cannot be explained in this way. Subtest 5,

Appendix A: Contentives, and Subtest 4 are also presumed to involve lexical processing strategies. It is possible that measures of lexical reading are less able to differentiate readers at different levels of proficiency than measures of phonological reading.

Specific Prediction 2

It was predicted that normal and superior readers would not have different error rates on the BARF. This prediction received partial support. Normal readers did not differ from superior readers on Subtests 1, 2, and 6 and Appendix A: Functors. However, normal readers made significantly more errors than superior readers on the BARF as a whole and on Subtests 3 and 4. These findings suggest that normal and superior readers are equally proficient on those subtests believed to be associated with a phonological route. Their relative proficiency with the lexical route is less clear since differences emerged on Subtests 3 and 4 but not Subtest 5. These findings also demonstrate the absence on a ceiling effect for errors on the BARF among normal and superior readers.

Specific Prediction 3

Superior readers were predicted to have more rapid response times than normal readers on the BARF. This prediction was clearly not supported. The response times of these two groups were not significantly different on any of the BARF subtests. Thus, the greater accuracy on the BARF demonstrated by superior readers was not accompanied by more rapid processing. Normal readers were able to process BARF stimuli just as rapidly, suggesting that a ceiling for response latency may have been reached. It is also possible that a

device more accurate than the manually operated stopwatch might have been able to detect subtle response time differences between these groups.

Additional Findings

No specific predictions were made regarding qualitative performance differences between reading groups. However, such differences were discovered. These differences fall into two categories: (a) differential patterns of performance across BARF subtests and (b) difference in the distribution of error types.

Performance across BARF subtests. The pattern of performance across subtests was examined within three, theoretically related groups of BARF subtests: (a) Subtests 1 - 4, (b) Subtests 5 - 6, and (c) Appendix A: Functors and Appendix A: Contentives. The pattern of response times across subtests was highly similar for each reading group and will not be discussed here. The patterns of subtest error rates associated with each reading group were observed to differ in the following ways.

Impaired and normal readers made more errors on Subtests 1 and 4 as compared to Subtests 2 and 3. However, the error rates on Subtests 1 and 4 were not significantly different. In contrast superior readers had significantly more difficulty with the nonwords of Subtest 1 than with the irregular words of Subtest 4. All three groups performed significantly better on Subtests 2 and 3. While superior readers performed similarly on these two subtests, normal and impaired readers performed significantly better on Subtest 2. Thus, an advantage for regular words relative to rule governed words was

present in impaired and normal readers, but not in superior readers. Normal and superior readers performed similarly on Subtests 5 and 6 and on Functors and Contentives. Impaired readers were characterized by significantly poorer performance on Subtest 6 relative to Subtest 5 and on Functors relative to Contentives.

Several issues are raised by the patterns described above. First, both normal and impaired readers appear to be experiencing equivalent difficulty with nonwords and irregular real words. If both reading routes were available, nonwords should be the most difficult category of stimuli based on their unfamiliarity. This is the pattern associated with the superior reading group. High error rates with both word types could reflect impairment of both phonological and lexical mechanisms. However, it also might be the result of combining data associated with dissociable subtypes into a single group. Both of these explanations are congruent with expectations for the impaired group but the presence of this pattern in normal readers is surprising. It suggests the need for careful examination of this group's members in the planned attempt to identify subtypes in this population.

Both normal and impaired readers also have more difficulty with rule governed words than with regular words. Rule governed words can be recognized either through the direct lexical route or by a grapheme-to-phoneme conversion process that includes an awareness of the complex, context sensitive rules of English orthography. Since normal and impaired readers may be having difficulty with both reading mechanisms, as suggested by their poor performance on both Subtests 1

and 4, the difficulty with rule governed words on Subtest 3 could be expected.

Finally, impaired readers as a group experience difficulty with Subtest 6 which requires phonological processing relative to Subtest 5 and with Functors relative to Contentives. These two characteristics have been associated with lexical reading. Their predominance in the impaired readers suggests that reliance on a lexical route characterizes the majority of these impaired readers. Again, this constitutes preliminary information about the nature of potential subtypes in this population. Further discussion of subtypes is reserved for a later section.

Distribution of error types. Errors were initially classified into six types (see Appendix 9). Prior to statistical analyses, these six types were combined to form three broad categories of errors. Phonological and visual-phonological errors were combined into a Phonological category. Semantic, visual, and derivational errors made up a Lexical category. Errors which did not meet the criteria for any of these types remained in an Other category. Finally, a Lexicalization Index was computed to reflect the percentage of real word responses to nonword targets on Subtest 1.

Impaired readers made significantly fewer Phonological errors and significantly more Lexical and Other errors than normal and superior readers. The error type distributions of normal and superior readers were not significantly different. The Lexicalization Index did not significantly differ as a function of reading group.

Thus, errors typically associated with lexical reading were more frequent in impaired readers. These errors were predominantly visual errors. Semantic errors were extremely rare. Only two clear examples were noted in the protocols of 30 subjects (e.g., "anthem" for "hymn"; "pretty" for "beauty"). Other more equivocal responses were also rated as semantic errors due to the liberal criterion used (e.g., "boom" for "bomb"). These data suggest that the reader with a developmental reading disorder is rarely, if ever, forced to rely on a direct lexical/semantic pathway in the way that a patient with the acquired reading disorder termed deep dyslexia does.

Although impaired readers made more lexical errors than normal and superior readers, the majority of errors for all reading groups were Phonological. Even among impaired readers, 78% of all errors made fell into this category. Almost all of these errors were initially classified as visual-phonological errors; pure phonological errors were extremely rare. It is not surprising that most error responses are both visually and phonologically similar to targets. However, to classify all errors as visual-phonological does little to illuminate the specific nature of impaired and spared processing mechanisms. The criteria developed for this investigation emphasize the physical characteristics of the target words and determine visual and phonological similarity by directly comparing graphemes and phonemes. While this system enhanced the reliability of error type judgments, it may have also obscured the mechanism underlying an incorrect response. A system of classification based on inferred mechanism would allow meaningful distinctions to be made among the

large number of errors that both look like and sound like the target. However, this benefit would most likely be accompanied by the cost of reduced reliability.

The need to focus on underlying mechanisms is most apparent for Phonological errors. Phonological processing of written material is a highly complex activity which can be broken down into several subskills. This fact is often not reflected in current models which typically reduce this route to a single black box called "grapheme-phoneme correspondence rules." In addition, this box is often believed to house the complex rules of English orthography as well. The appreciation and appropriate application of these rules is a completely different process than the ability to pair graphemes with corresponding phonemes. Temple (1985) has identified three substages of the phonological route, referred to as the parser, the translator, and the blender. She presents cases of surface dyslexia, both acquired and developmental, whose patterns of performance suggest a specific deficit in one of these stages. Temple's paradigm represents an important direction for future investigations of reading routes. Identification of the component skills involved in hypothesized reading mechanisms will allow a more accurate identification of specific deficits and ultimately lead to more precise models of the reading process.

Conclusions

The performance of impaired readers was significantly poorer than that of normal and superior readers on the BARF. It is not remarkable that poor readers do poorly on a measure of reading. However, this

investigation does support the effectiveness of the BARF as an instrument that is able to differentiate children who differ in reading achievement as measured by a standard instrument. No floor or ceiling effects for accuracy occurred across a wide range of reading abilities in a population of 12-year-old males. Both error rate and mean response time were useful in differentiating children with different reading skills although response time was not useful at the upper end of the ability range. Finally, readers of different ability performed in qualitatively different ways on the BARF. In general, impaired readers had greater difficulty with tasks that relied on phonological processing. They also made errors reflecting a lexical reading mechanism more frequently than normal and superior readers.

These findings also demonstrate the importance of rapid word recognition skills in achieving fluency in reading comprehension. Individuals who have difficulty with single word recognition may need to rely heavily on surrounding context to recognize individual words in printed text. It is possible that an overinvestment of cognitive resources in the recognition process may result in fewer available resources for higher order comprehension skills.

General Hypothesis 2

Models of acquired alexia are based on the notion of multiple routes to reading. The most common model postulates two routes, a sequential, phonological strategy and a simultaneous or wholistic, lexical strategy. Subtypes of acquired alexia have been identified based on the disruption of one of these routes with relative sparing of the other (Marshall & Newcombe, 1966, 1973). This investigation

explored the utility of this model of alexia for identifying subtypes of children with developmental reading disorders. The BARF was administered to children across a wide range of reading ability. This measure was chosen based on its ability to separate and independently assess the phonological and lexical reading mechanisms in adults. It was hypothesized that subtypes, based on pattern of performance on the BARF, would be identifiable only within impaired readers. Normal and superior reading ability is likely to require the contribution of both strategies. Thus, subtypes based on the relative impairment and preservation of these two routes were not expected in these two groups.

Specific Prediction 4

Within the group of impaired readers, three subtypes were predicted. The first two subgroups were characterized by impairment in one reading route with relative sparing of the other. The predicted phonological reading subtype was characterized by impairment in the lexical route, corresponding to the description of surface dyslexia by Marshall and Newcombe (1966, 1973). These subjects would have difficulty reading irregular words (Subtest 4) and distinguishing homophones (Subtest 5). Their errors would primarily reflect phonological processing. Finally, they would not have difficulty with functors relative to contentives or show a tendency to lexicalize when asked to pronounce nonwords.

The predicted lexical reading subtype was characterized by impairment in the phonological route, corresponding to the description of deep dyslexia by Marshall and Newcombe (1966, 1973). These

subjects would have difficulty reading nonwords (Subtests 1 and 6) and would make errors reflecting a lexical strategy. They would have difficulty with functors and have a tendency to lexicalize nonwords.

A third subtype, described as a mixed deficit reading group, was also predicted. It seemed probable that deficits would be present in both routes in some children. These subjects would have difficulty with both nonwords (Subtests 1 and 6) and irregular words (Subtest 4). They would have difficulty distinguishing homophones (Subtest 5) and would make errors reflecting both strategies as well as a number of Other errors which could not be classified. They should also show some tendency to lexicalize and have equal difficulty with functors and contentives. These children are likely to have the most severe reading deficits.

Two methods were used to identify subtypes. A method of cluster analysis which allowed the specification of predicted mean profiles was chosen. Subjects were also grouped according to a set of classification rules using a visual inspection technique. The results of these two approaches to subtype identification will be discussed separately and compared.

Cluster analysis. Five clusters were predicted containing (a) superior readers, (b) normal readers, (c) lexical readers, (d) phonological readers, and (e) readers with deficits in both reading routes. The clustering program selected will create the number of clusters specified, so five clusters were necessarily present in the solution. These clusters were examined to determine their congruence with the predicted subtypes and to identify the initial reading group

of cluster members. Those clusters predicted for the impaired readers (i.e., Lexical, Phonological, and Mixed Deficits) will be discussed here. Further discussion of clusters predicted for normal and superior readers will appear under Specific Prediction 5.

Examination of the cluster means and standard deviations for the seed variables revealed that in most cases, the general shape and elevation of the seed profile was maintained. The majority of profile changes occurred in the Lexical cluster. Members of the Lexical cluster did not perform more poorly on nonwords than irregular words as predicted, but had difficulty with both word types. It was also predicted that Lexical and Phonological readers would have similar overall error rates. In fact, Lexical readers made many more errors than Phonological readers, although not as many as Mixed Deficits readers. Finally, the profile for Mixed Deficits readers was altered in the direction of the Lexical readers profile, suggesting that the phonological deficit may be more severe than the lexical deficit in these children.

Subjects were distributed fairly equally across the three predicted clusters (Lexical = 13, Phonological = 17, Mixed Deficits = 20). Since the number of subjects placed in these clusters greatly exceeded 30, it was clear that some normal and/or superior readers were present in these groups. Twenty percent of Mixed Deficits readers and 38% of Lexical readers came from either the normal or superior reading groups. However, 76% of those readers in the Phonological group were either normal or superior readers. Thus, it appears that while normal and superior reading achievement is possible

with deficits in the phonological route, it is more likely to occur in those children with deficits in lexical processing with an intact phonological route. The strong relationship between phonological deficits and reading impairment is also supported by the apparent predominance of phonological deficits in the Mixed Deficits cluster.

In summary, the evidence suggests that phonological deficits have a stronger relationship with reading impairment than do lexical deficits. While many children with deficient lexical processing were able to have normal and superior reading achievement, this outcome was much less likely for children with phonological deficits. It also appears that phonological deficits do not occur in isolation but are accompanied by a lesser degree of impairment in the lexical route. Those children who had difficulty with phonological tasks showed unexpected deficits on lexical tasks as well.

Classification rules. Visual inspection techniques were used to classify subjects into Lexical and Phonological readers, based on a set of classification rules (see Appendix 10). Subjects who did not meet the criteria for either subtype were placed in an Unclassified group. The majority of impaired readers either met all the criteria for Lexical readers or met all except one (53%). Forty percent of impaired readers were Unclassified and only 7% were classified as Phonological readers. The use of simple visual examination made it difficult to characterize those readers who could not be classified as either Phonological or Lexical readers. Their performance revealed no clear preference for either route with poor performance on all

tasks. It is likely that this group corresponds to the Mixed Deficits group defined by cluster analysis. These findings are consistent with the cluster analysis solution. They suggest that the vast majority of poor readers have deficits in the phonological and/or both reading routes. Poor readers with impaired lexical reading and intact phonology (i.e., developmental surface dyslexics) are quite rare.

Specific Prediction 5

Normal and superior reading ability are assumed to require the use of both processing routes. It was predicted that phonological and lexical subtypes would not be found within groups of normal and superior readers. Cluster analytic and visual inspection methods were also used to search for subtypes in these two groups of readers.

Cluster analysis. Seed profiles for Normal and Superior clusters were entered into the clustering program. These profiles differed quantitatively but not qualitatively. Cluster means for errors on Subtests 1 and 4 were elevated for both the Normal and Superior clusters relative to predicted levels. Thus, predicted profiles somewhat underestimated the rate of errors in these two populations. The shapes of the two seed profiles were maintained in the solution, with the exception of unexpectedly low Lexicalization Index and relative difficulty with functors in the Superior cluster.

The Superior cluster was the smallest cluster in the solution with nine members and the Normal cluster the largest, with 31 members. The small number of Superior cluster members appears to be the result of underestimating the level of overall performance in this population. Consequently, only the most proficient readers were

placed in this cluster. The majority of the remaining superior readers were placed in the Normal cluster along with approximately one-third of normal readers and two impaired readers. These two impaired readers represented the top of the distribution of reading achievement scores in the impaired group.

However, a small percentage of superior readers and a sizeable percentage of normal readers were placed in clusters designated to contain subtypes of impaired readers. Both superior and normal readers appeared in the Lexical and Phonological clusters. They were much more likely to be placed in the Phonological cluster, as discussed above. No superior readers were placed in the Mixed Deficits cluster although four normal readers did appear in this group.

These findings do not support the prediction that subtypes would not be present in normal and superior readers. While the majority of superior readers do not appear to rely on either route to the exclusion of the other, at least 17% could be subtyped based on such a preference. Eighty percent of these were phonological readers; 20% were lexical readers. Among normal readers, 43% could be placed in one of the three subtype clusters. Again, the majority of children were phonological readers (52%) while 24% were lexical readers and 24% had mixed deficits. These results suggest that it is possible to attain normal and occasionally superior reading achievement by relying primarily on only one strategy. However, this level of achievement is much less likely if the phonological route is deficient.

Classification rules. Classification by visual inspection also provided support for the presence of subtypes in normal and superior readers. As in the cluster analysis, subtypes were more prominent in the normal reading group. However, the predominance of phonological readers revealed by cluster analysis was not replicated by this method. Eighty-six percent of superior readers were Unclassified, with the remainder equally divided between Phonological and Lexical groups. Fifty-seven percent of normals were unclassified and again roughly equal percentages of the remainder were placed in the two subtypes (Lexical = 23%; Phonological = 20%).

Conclusions. These findings clearly support the existence of a subtype analogous to deep dyslexia (i.e., lexical readers) among children with developmental reading disorders. However, since semantic errors were extremely rare in this group, phonological alexia may be a more appropriate model. Patients with phonological alexia are unable to read nonwords and have difficulty with other tasks that require phonological processing, but do not make semantic errors. Results also support the existence of a subtype in which both reading routes are impaired. There is less support for the existence of a developmental analogue for surface dyslexia (i.e., phonological readers) in the population of impaired readers. Only 13% of poor readers were classified as phonological readers. In fact, the data suggest that reliance on a phonological route is frequently associated with normal or even superior reading achievement while lexical readers are much less likely to achieve normally.

These data are consistent with Frith's (1985) model of reading development which postulates an invariant sequence of stages: (a) logographic, (b) alphabetic, and (c) orthographic. She proposes that distinct developmental disorders result from arrests at the logographic stage and at the alphabetic stage. Logographic reading skills refer to the instant recognition of familiar words based on salient visual features. Failure to develop such skills, while theoretically possible, is extremely rare. Even children with severe cognitive deficits are able to develop a limited sight vocabulary.

Developmental arrest at the logographic stage would prevent the acquisition of alphabetic skills, i.e., the knowledge and use of grapheme-phoneme correspondences. However, Frith (1985) points out that development continues from the point of arrest, along an abnormal, compensatory path. It is likely that the child without alphabetic skills, extends his use of logographic skills and may even develop some resemblance of orthographic skills. However, phonological processing deficits remain. According to Frith, failure to develop alphabetic skills defines "classic developmental dyslexia." The findings of this study support the predominance of this deficit in poor readers.

Arrest at the alphabetic stage is also possible in this model. Children who have reached this point have attained both logographic and alphabetic skills. Frith (1985) views the transition to the orthographic stage as a merging of the instant recognition and analytic sequential skills developed in the two previous stages. This allows the reader to utilize orthographic units in reading, rather

than relying on graphic features or grapheme-phoneme correspondences. It is possible that the presence of both types of skills allows for normal reading competency. Children who arrest at the alphabetic stage may achieve this level of proficiency but fail to develop increased reading fluency due to the lack of orthographic skills. Frith proposes that arrest at the alphabetic stage be referred to as "developmental dysgraphia" since the primary deficit in these children would be in spelling irregular words.

Unfortunately, no measures of spelling were obtained in this study, to further evaluate Frith's (1985) model. However, this model does appear to fit the two primary findings of the subtype analysis:

1. Impaired readers are characterized by deficits in the phonological route;
2. The ability to use the phonological route permits normal reading achievement even in the absence of well developed lexical skills.

Another potential explanation for the first finding was considered. The racial distributions of each reading group were quite different. Although analyses of variance demonstrated that race did not account for a significant portion of the quantitative variance between groups, qualitative differences between black and white children were possible. Mack, Gonzalez-Rothi, and Scott (1986) examined <u>BARF</u> performance in a small sample of Black adult males. They found that Black English dialect speakers were able to read all real words but had great difficulty with nonwords. This pattern was not found in Black males who did not speak in the Black English

dialect. These authors propose that Black English speakers do not use a General American English letter-sound conversion route. Consequently, they appear to have phonological deficits with intact lexical processing.

Over half of the impaired readers in this study were Black. The predominance of this reading pattern in the impaired group may have been a reflection of its racial composition. No information about dialect had been obtained during the course of this investigation. However, the racial distributions of the lexical and nonlexical groups (i.e., Phonological and Unclassified) could be compared. Although these did not differ, it is possible that those children in the Lexical group spoke Black English dialect while those in the other groups spoke General American English. Thus, the contribution of dialect to reading performance remains unexplored and represents a potential confound in studies of developmental reading disorders.

General Hypothesis 3

The Brigance Diagnostic Inventory of Basic Skills (Brigance, 1977) was chosen to assess silent reading comprehension and reading rate. This measure provided an independent assessment of reading comprehension with a format similar to the Metropolitan Achievement Test (1978). Reading rate represents another dimension of fluent reading which is likely to be related to the type of processing employed as well as to general level of proficiency. Thus, quantitative performance differences between subjects on the Metropolitan Achievement Test should also be present on the Brigance. Three specific predictions were tested.

Specific Prediction 6

Impaired readers were predicted to differ from normal and superior readers in terms of both speed and accuracy on the Brigance. No differences in accuracy were found. This unusual finding appears to be attributable to the decision to provide subjects with passages to read which were commensurate with their reading grade levels as measured by the Metropolitan Achievement Test. This allowed for a comparison of reading rates by equating passage difficulty relative to each subject's level of ability. Unfortunately, this manipulation appears to have removed the variance related to reading proficiency. Impaired readers did have significantly slower reading rates than normal and superior readers. Thus, this prediction received partial support. These findings suggest that reading speed is another relevant dimension of general reading ability which is related to those aspects of reading tapped by the Metropolitan Achievement Test.

Specific Prediction 7

It was predicted that normal and superior readers would not have significantly different error rates on the Brigance. This prediction was supported. However, it is likely that this finding also reflects the manipulation of passage difficulty as discussed above. As a result, this finding is not informative regarding the relative comprehension skills of these two groups.

Specific Prediction 8

Superior readers were predicted to have more rapid reading rates than normals on the Brigance. The differences between these two

groups in reading rate were significant. This finding is not surprising. It is likely that one of the primary characteristics of superior reading skill is the ability to read rapidly without a consequent loss of accuracy.

General Hypothesis 4: Specific Prediction 9

The two hypothesized reading routes should differ in processing speed. Since the lexical route employs a simultaneous, wholistic process it should be more rapid than the phonological route which requires a sequential, analytic approach. Thus, reading rate on the Brigance was chosen as a variable with which to assess the external validity of the Lexical and Phonological clusters. It was hypothesized that pattern of performance on the BARF would be related to reading rate on the Brigance.

It was predicted that subjects whose performance on the BARF suggests a lexical route would have more rapid reading rates than subjects whose performance suggests a phonological route. This prediction was not supported. Although the difference between these two groups was in the expected direction it did not reach statistical significance. These results do not support the external validity of the cluster solution at least with regard to this particular variable. However, there were significant differences between clusters which appeared to reflect differences in general reading proficiency. The Superior cluster had a significantly faster reading rate than the Lexical, Phonological, and Mixed Deficits clusters. The Normal cluster read more rapidly than the Phonological and Mixed

Deficits clusters. It is interesting to note that although members of the Phonological cluster made fewer errors and had much higher levels of reading achievement than members of the Lexical cluster, they still read more slowly. Thus, it seems likely that a variety of other factors, such as overall proficiency and experience, interact with reading route to determine an individual's reading rate.

Summary and Conclusions

The utility of the Battery of Adult Reading Function (Gonzalez-Rothi et al., 1984) in differentiating children who differ in reading achievement was demonstrated by this investigation. Poor readers were shown to differ both quantitatively, in terms of error rate and response latency, and qualitatively, in terms of error type and subtest scatter, from normal and superior readers. These findings also demonstrate the importance of rapid word recognition in the reading comprehension process.

The BARF was also useful in identifying subtypes of impaired readers. Contrasting methods of subtype identification were shown to produce congruent results. Reading impairment was primarily characterized by a deficit in the phonological route. Impaired readers with a selective deficit in the lexical route and spared phonological processing were extremely rare. In fact, the selective impairment of the lexical route allowed for normal and occasionally superior reading achievement in the majority of subjects. Finally, subtypes could be identified in normal readers and possibly in superior readers. Subtypes of readers who primarily rely on a single

processing strategy are not unique to poor readers. Thus, selective impairment of one reading route cannot account for reading impairment. However, the rarity of subtypes in the superior group does suggest that the availability of both reading mechanisms is involved in the development of superior reading ability. These findings are congruent with the model of reading development proposed by Frith (1985).

Children with different levels of reading achievement had different reading rates for connected prose. The reading rates of phonological and lexical readers were not significantly different. Thus, reading rate was not clearly related to reading route. The preferred route may interact with other aspects of reading performance to determine an individual's reading rate.

Two other general issues are raised by this study. The first involves the use of models of acquired disorders to understand developmental disorders. Models of skilled reading cannot address questions that are essential to a developmental model (Frith, 1985). How do the various skills employed by the mature reader come into being? It is unlikely that the newborn brain is equipped with a fully developed grapheme-phoneme converter. However, it is reasonable to assume that certain brain structures are present at birth which will subserve basic cognitive processes necessary for reading. Failure to develop normal reading proficiency can result from impairment of these structures themselves, from a deficit in developmental processes, either maturational or experiential, or from some interaction of the two. How can these developmental processes be characterized and how

do they act on brain structures? What is the course of developmental change? Is it steady and gradual or stepwise with both regressive and progressive leaps and plateaus?

Awareness of these questions does not imply that comparisons of developmental and acquired dyslexia are irrelevant. However, these comparisons are more meaningful when they are accompanied by an explicit model of reading development. Frith's (1985) model addresses these questions and provides a useful framework for understanding the findings of this investigation.

Finally, some comments on methodology are in order. The cluster analysis technique used in this study differs significantly from the techniques chosen by other investigators who have used cluster analysis to identify subtypes of learning disabilities. Other techniques allow the data to sort as it will, without reference to theoretical preconceptions. The clusters formed are then examined carefully to determine their characteristics. Labelling and describing the derived clusters occurs post hoc.

The FASTCLUS procedure allows the investigator to test a theoretical model by forming clusters around predicted mean profiles. This method is not designed to discover the hidden structure of the data set. It is more appropriate for testing the utility of a specific model in which particular subtypes are expected.

Previous investigations of learning disability subtypes have predominantly been atheoretical. Many have moved away from studying reading performance to exploring related neuropsychological variables without clear explanations of how these variables support or interact

with the reading process. Few studies have studied normal and superior readers to see if similar subtypes occur in these groups. This study represents an attempt to address these deficits. The cluster analytic technique utilized here combines the strengths of both clinical-inferential and multivariate statistical classification methods. It makes use of the wealth of clinical information contained in a theoretical model. At the same time, it brings statistical techniques to bear on multivariate data sets which overwhelm the clinician's eye.

APPENDIX 1
INFORMED CONSENT

Informed Consent to Participate in Research

J. Hillis Miller Health Center
University of Florida
Gainesville, Florida 32610

You are being asked to volunteer as a participant in a research study. This form is designed to provide you with information about this study and to answer any of your questions.

1. Title of Research Study

   Phonologic and Lexical Routes to Reading: A Comparison of Impaired, Normal, and Superior Readers

2. Project Director

   Name: Mary K. Morris, M.S.
   Telephone Number: (904) 392-4551

3. The Purpose of the Research

   This study is designed to assess the strategies that children use to read aloud familiar and unfamiliar words. We are interested in learning about which strategy or combination of strategies lead to better reading ability. This information can be used to better understand what causes specific reading problems in children, as well as to develop more effective treatments for reading disability.

4. Procedures for this Research

   Two reading tests will be administered.

   The first requires the subject to read aloud real words and nonsense words and to match written words to pictures.

   The second requires the subject to read aloud a short story and answer questions about it.

The testing will take approximately 1 hour.

The information from these tests will be compared to the subject's reading achievement scores obtained from school records.

5. Potential Risks or Discomforts

The only risk/inconvenience is the minor requirement of time for testing (1 hour).

If you wish to discuss these or any other discomforts you may experience, you may call the Project Director listed in #2 of this form.

6. Potential Benefits to You or to Others

There are no direct benefits to the individual subject. However, information from this study may contribute to a greater understanding of the causes of reading problems in children and the development of better treatments.

7. Alternative Treatment or Procedures, If Applicable

The study is entirely voluntary; no portion of the testing is necessary.

8. General Conditions

I understand that I will ___/will not _x_ receive money for my participation in this study. If I am compensated, I will receive ______________________________.

I understand that I will ___/will not _x_ be charged additional expenses for my participation in this study. If I am charged additional expenses these will consist of __________.

I understand that I am free to withdraw my/my child's consent and discontinue participation in this research project at any time without this decision affecting my/my child's medical care.

In the event of my/my child sustaining a physical injury which is proximately caused by this experiment, no professional medical care received at the J. Hillis Miller Health Center exclusive of hospital expenses will be provided me without charge. This exclusion of hospital expenses does not apply to patients at the Veterans Administration Medical Center (VAMC) who sustain physical injury during participation in VAMC-approved studies. It is understood that no form of compensation exists other than those described above.

All data obtained from this research will remain confidential. The University of Florida will protect the confidentiality of this document and your records from this research to the extent provided by law.

9. Signatures

I have fully explained to ______________________________ the nature and purpose of the above-described procedure and the benefits and risks that are involved in its performance. I have answered and will answer all questions to the best of my ability. I may be contacted at telephone number _______________.

____ ____________________
Signature of Person Obtaining Consent Date

I have been fully informed of the above-described procedure with its possible benefits and risks and I have received a copy of this description. I have given permission of my/my child's participation in this study.

____ ____________________
Signature of Patient or Subject of Relative or Parent or Guardian (specify) Date

____ ____________________
Signature of Child (7 to 17 yrs. of age) Date

____ ____________________
Signature of Witness Date

APPENDIX 2
SUBTEST 1: BATTERY OF ADULT READING FUNCTION
(GONZALEZ-ROTHI ET AL., 1984)

			Error Type					
Trial	+/-	Transcription	semantic	phonologic	visual	visual/ phonologic	derivation	other
1. trad								
2. pable								
3. terriage								
4. manver								
5. jisp								
6. birough								
7. ziller								
8. quim								
9. vatter								
10. blime								
11. soud								
12. cimy								
13. scomb								
14. illend								
15. trooge								
16. crang								
17. pheke								
18. thuse								
19. slem								
20. slig								
21. tralf								
22. strick								
23. barcle								
24. mofer								
25. isleck								
26. vyte								
27. andon								
28. intret								
29. theaway								
30. nace								
Total								
% Correct								

APPENDIX 3
SUBTEST 2: BATTERY OF ADULT READING FUNCTION
(GONZALEZ-ROTHI ET AL., 1984)

			Error Type					
Trial	+/-	Transcription	semantic	phonologic	visual	visual/ phonologic	derivation	other
1. transfer								
2. neglect								
3. mask								
4. pitiful								
5. motor								
6. sink								
7. forget								
8. holder								
9. admit								
10. holy								
11. injury								
12. maker								
13. factor								
14. hunter								
15. damp								
16. pinch								
17. submit								
18. corn								
19. divine								
20. hotel								
21. grand								
22. halter								
23. open								
24. inform								
25. veteran								
26. vent								
27. star								
28. darn								
29. stand								
30. match								
Total								
% Correct								

APPENDIX 4
SUBTEST 3: BATTERY OF ADULT READING FUNCTION
(GONZALEZ-ROTHI ET AL., 1984)

Trial	+/-	Transcription	Error Type: semantic	phonologic	visual	visual/ phonologic	derivation	other
1. ritual								
2. tight								
3. ninth								
4. debt								
5. sign								
6. marriage								
7. comrade								
8. wealth								
9. prairie								
10. comb								
11. beast								
12. kneel								
13. limb								
14. symbol								
15. health								
16. pier								
17. foreign								
18. heaven								
19. doubt								
20. ledge								
21. eighty								
22. belief								
23. word								
24. reign								
25. scent								
26. sigh								
27. beauty								
28. height								
29. knob								
30. wrap								
Total								
% Correct								

APPENDIX 5
SUBTEST 4: BATTERY OF ADULT READING FUNCTION
(GONZALEZ-ROTHI ET AL., 1984)

Trial	+/-	Transcription	Error Type: semantic	phonologic	visual	visual/ phonologic	derivation	other
1. mischief								
2. tomb								
3. honor								
4. deny								
5. circuit								
6. heir								
7. engine								
8. bouquet								
9. shoes								
10. weapon								
11. chord								
12. yacht								
13. palace								
14. friend								
15. busy								
16. isle								
17. corps								
18. answer								
19. buoys								
20. hymn								
21. breast								
22. earth								
23. menace								
24. bomb								
25. sure								
26. glacier								
27. morgue								
28. subtle								
29. aisle								
30. yolk								
Total								
% Correct								

APPENDIX 6

SUBTEST 5: BATTERY OF ADULT READING FUNCTION

(GONZALEZ-ROTHI ET AL., 1984)

Trial	Stimuli	
Practice	ARC	ark
Practice	MAIL	male
1.	SEA	see
2.	CLOSE	clothes
3.	knight	NIGHT
4.	hair	HARE
5.	slay	SLEIGH
6.	YOLK	yoke
7.	HOES	hose
8.	CHORD	cord
9.	flea	FLEE
10.	BALD	bawled
11.	CAUGHT	cot
12.	CELL	sell
13.	FIR	fur
14.	ring	WRING
15.	rows	ROSE
16.	pain	PANE
17.	pair	PEAR
18.	son	SUN
TOTAL		
% Correct		

APPENDIX 7
SUBTEST 6: BATTERY OF ADULT READING FUNCTION
(GONZALEZ-ROTHI ET AL., 1984)

Trial	Stimulus	Response		
Practice	coam	A	b	c
Practice	bomm	a	b	C
1.	prarey	A	b	c
2.	yott	a	B	c
3.	ile	a	b	C
4.	paleese	A	b	c
5.	shooz	a	B	c
6.	shofer	A	b	c
7.	bild	a	B	c
8.	wepun	a	b	C
9.	rane	a	B	c
10.	niel	a	B	c
11.	erth	a	b	C
12.	yoak	a	b	C
13.	aytee	A	b	c
14.	booie	a	b	C
15.	rapt	a	B	c
16.	hevin	a	b	C
17.	endjen	A	b	c
18.	sine	A	b	c
TOTAL				
% Correct				

APPENDIX 8
APPENDIX A: BATTERY OF ADULT READING FUNCTION
(GONZALEZ-ROTHI ET AL., 1984)

	+/-		
Trial	Functor	Contentive	Transcription
1. although			
2. however			
3. general			
4. money			
5. help			
6. whose			
7. shall			
8. college			
9. thus			
10. ever			
11. best			
12. should			
13. interest			
14. upon			
15. part			
16. people			
17. though			
18. taken			
19. number			
20. already			
21. almost			
22. maybe			
23. united			
24. method			
25. deep			
26. leader			
27. whom			
28. none			
29. nearly			
30. club			

Trial	Functor +/-	Contentive	Transcription
31. else			
32. trial			
33. live			
34. always			
35. among			
36. point			
37. public			
38. whether			
39. where			
40. years			
41. major			
42. nobody			
43. history			
44. state			
45. quite			
46. work			
47. still			
48. each			
49. long			
50. high			
51. both			
52. once			
53. small			
54. every			
55. things			
56. looked			
57. within			
58. church			
59. matter			
60. itself			
TOTAL			
% Correct			

APPENDIX 9

ERROR TYPE CLASSIFICATION CRITERIA

1. Semantic: a semantic associate of the target scored even if visually and/or phonologically similar.

2. Phonologic:

	a.	50% of response phonemes appear in target;
and/or	b.	phonemes correct, stress on wrong syllable;
and/or	c.	response results from misapplication of orthographic rules;
and/or	d.	response reflects use of grapheme to phoneme conversion strategy with an irregular word.

3. Visual: 50% of response graphemes appear in target. (Nonwords judged based on conversion of response phonemes to corresponding graphemes.)

4. Visual/Phonological: meet the criteria for both visual and phonologic as above.

5. Derivational: response and target share a common root morpheme.

6. Other: any not included above.

APPENDIX 10
SUBTYPE CLASSIFICATION RULES

I. Phonological readers

1. Error % (4) > Error % (1)
2. Lexicalization Index $\leq$ 30%
3. Error % (5) > Error % (6)
4. Error % (Functors) $\leq$ Error % (Contentives)
5. Lexical errors $\leq$ 10% of total errors
6. No semantic errors

II. Lexical readers

1. Error % (1) > Error % (4)
2. Lexicalization Index > 30%
3. Error % (6) > Error % (5)
4. Error % (Functors) > Error % (Contentives)
5. Lexical errors > 10% of total errors
6. Semantic errors not necessary, but occurrence is strongly suggestive of this subtype.

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BIOGRAPHICAL SKETCH

Mary Kathleen Morris was born on September 30, 1957, in Williamsport, Pennsylvania. She was reared there and graduated from Williamsport Area High School in 1975. She attended Cornell University where she received a Bachelor of Arts degree in psychology and was elected to Phi Beta Kappa in 1979. In September 1980, she enrolled at the University of Florida to pursue a doctorate in clinical psychology. Her Master of Science degree was awarded in 1984. Continued training included completion of concentrations in neuropsychology and child clinical psychology and internship training in the Department of Psychiatry, George Washington University Medical Center. Following completion of this degree, she will be employed as a pediatric psychologist by Riverside Hospital, Newport News, Virginia.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Eileen B. Fennell

Eileen B. Fennell, Chairperson
Associate Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Russell M. Bauer

Russell M. Bauer
Associate Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Jacquelin R. Goldman

Jacquelin R. Goldman
Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Kenneth M. Heilman

Kenneth M. Heilman
Professor of Neurology and Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Leslie J. Gonzalez Rothi

Leslie J. Gonzalez-Rothi
Assistant Professor of Speech

This dissertation was submitted to the Graduate Faculty of the College of Health Related Professions and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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Dean, College of Health Related Professions

Dean, Graduate School